

An Historical Study of the Design of Retorts  
for Mineral Oil Production, with particular  
reference to the Scottish Shale Oil Industry.

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## I. INTRODUCTION

Natural petroleum products such as pitch, heavy residue oils, naphtha and gas obtained from ground seepages, were known to the ancient civilisations of Asia, but refined petroleum oils, lubricants and waxes did not become available in Europe and America until after 1859 when Col. E.L. Drake bored the world's first oil well at Oil Creek in Pennsylvania.

Mineral oils were however in use in the West, although to a very limited extent, long before this date, the source being a variety of solid carbonaceous mineral substances which were found to yield oil on destructive distillation.

British patent records show that bituminous coal was distilled for the production of oil (apart from its known yield of gas) as early as the year 1681 and the numerous patents which were taken out in the 18th and 19th centuries give some indication of the intensity of the search which was made for suitable raw materials and for methods of obtaining the liquid products therefrom.

While the majority of the earlier British patents specified coal and associated minerals as the oil source, definite reference was not made to oil shales until 1841 when Count de Hompesh took out a patent on the production of oil from "bituminous schists". This patent and another by Du Buisson in 1845, protected in Britain the process which had already been patented in France by Selligue in 1838.

The raw material specified by Selligue was "bituminous schist" from the arrondissement of Autun in the Department of Saone et Loire. Shale oil had, however, been made from Autun "schists" by /



I. INTRODUCTION (Continued)

by Laurent in the year 1835 and shale oil products were shown by Selligue and de la Haye at the Paris Exhibition of 1839.

The shale oil industry, however, had its real beginning in Scotland in 1850 when Jas. Young was granted Patent No. 13292 on "Improvements in the treatment of certain bituminous mineral substances and in obtaining products therefrom" and when immediately thereafter he, in association with W. Meldrum and E.W. Binney, set up a plant at Bathgate, West Lothian, to carry out the process on a commercial scale.

Actually Young's patent made no reference to oil shale, but specified "parrot coal, cannel coal and gas coal", and for about ten years the locally occurring Boghead coal or Torbane mineral was extensively distilled in Scotland, and even exported to Germany and America for the same purpose.

When the reserves of this mineral were almost exhausted, a substitute was found in the oil shales of the Lower Carboniferous strata of central Scotland and oil shale has been used almost exclusively in the Scottish industry from about 1860 to the present day.

The earliest retorting plant was primitive in design and extremely wasteful in fuel, but following the establishment of an industry by Young, development in Scotland was rapid and continuous up to the beginning of the present century, and in more recent years established designs have had important modifications made to them.

The /

I. INTRODUCTION (Continued)

The historical aspect of retorting has already been briefly dealt with in general works on the Scottish Industry by:-

I.	2.	3.	4.	5.
F.J. Rowan,	D.R. Steuart,	I.J. Redwood,	B. Redwood,	S. Allen,
6.	7.	8.	9.	
H.R.J. Connacher,	Gavin,	Stewart and Forbes,	while two papers by	
10.	II.			
G.T. Beilby,	and Henderson,	Crichton & Bryson,	are purely historical	

but refer to certain periods only.

It is the purpose of the present investigation to make a study of the evolution of shale retort design in this country from the simple forms of the early days to the modern continuous retort designed for maximum yield of products at high throughput rates and with low fuel consumption.

While the theoretical development is traced out through the study of the British patent literature, particular reference is made to the actual working development of retorting plant as used in the Scottish Mineral Oil Industry during the last 90 years.

In the official Abstracts of British Patents, retorts for oil production are classified along with retorts and apparatus for gas manufacture. These abstracts have been studied and the oil producing retort patents collected and classified, but where further detail was considered necessary as in the case of the more important designs, reference was made to the full patent specifications.

Many retort designs, protected by patents, however, were never tried out in practice and on the other hand a number which were widely used were never patented at all.

To /

I. INTRODUCTION (Continued)

To obtain information on retorts long out of use, many possible sources have been investigated. Profitable research has been made in old working drawings, in correspondence and in evidence taken at law suits, while notes made during many conversations with workmen and officials once associated with the Scottish shale industry have also yielded much information.

## 2. THE INFLUENCE OF THE MARKET FOR THE PRODUCTS ON THE DESIGN OF OIL PRODUCING RETORTS.

The first practical forms of retort for producing oil from shales and cannels were very similar to, and no doubt were adapted from, existing horizontal iron retorts for coal gas. An important difference in their operation, however, was that in order to give the maximum yield of oil and the minimum gas make, oil retorts were heated to a lower temperature than similar coal gas retorts. These early intermittent horizontal iron retorts, largely because of their being worked without steam, gave a low gravity oil containing a large proportion of illuminating oil and little solid paraffin. The market demanded a mineral oil to replace the fish and animal oils then used for illuminating purposes and the refined product from crude shale and cannell oils consequently fetched a considerable price, as much as 2/6d per gallon being paid during the course of Jas. Young's patent. With the importation of petroleum Kerosene from America after the year 1862 and later from South Russia, the price fell to about 6d per gallon and the production of heavier oils and wax became more important.

The introduction of vertical iron retorts with the use of steam as an aid to distillation gave an increased yield of crude oil containing more solid paraffin while at the same time fuel was economised and semi-continuous operation made possible. Following the simple tubular vertical retorts came a variety of other forms, the aim of every designer being to heat the shale to a low and steady temperature to give the maximum yield of oil of low refining loss, coupled /



## 2. THE INFLUENCE OF THE MARKET FOR THE PRODUCTS ON THE DESIGN OF OIL PRODUCING RETORTS. (Continued)

coupled with economy in fuel consumption for retort heating.

Although the introduction of steam to externally heated vertical retorts was found to increase the yield of Ammonia, this was of secondary importance at first and indeed for a time the Ammonia liquor was difficult to dispose of.

Peruvian guano had long been used by the British farmer as an important source of combined nitrogen, but by 1880 it showed signs of becoming exhausted and Sulphate of Ammonia became of increasing importance and was valued at as much as £24 per ton. Sulphate of Ammonia was first made from shale ammonia liquor at Broxburn by <sup>12.</sup> R. Bell in 1865 and as the selling price of the product increased with the passage of time, shale retorts were lengthened and worked at a higher temperature with more steam, to increase the yield of ammonia. Ultimately in the year 1881 in their work on the recovery of combined Nitrogen, G.T. Beilby & W. Young applied the processes of Richters & Grouven to oil shale and introduced the principle of two stage retorting whereby the charge was heated gently to recover the oil and then heated strongly in presence of steam to give a maximum yield of ammonia and fuel gas. The first successful manually operated retort to carry out this double operation (the Pentland retort) was built in 1882/83 and by its wide adoption the yield of Sulphate of Ammonia was greatly increased and the shale distillation industry came to provide a considerable proportion of the nation's output of this valuable fertiliser. Unfortunately /

## 2. THE INFLUENCE OF THE MARKET FOR THE PRODUCTS OF THE DESIGN OF OIL PRODUCING RETORTS. (Continued)

Unfortunately the importation of Nitrate of Soda subsequently lowered the price of Sulphate of Ammonia, but the introduction of mechanically operated two stage retorts in the last decade of the 19th century, enabled greater quantities of low oil but high ammonia yielding shales to be processed profitably. Table No. I which has been made up from several sources shows how the yield of Sulphate of Ammonia increased out of proportion to the tonnage of mineral processed, first by the adoption of the Pentland type of retort and its mechanised forms up to the year 1900, secondly and later by the enforced use of shales giving a lower oil but a higher ammonia yield as the richer oil yielding shales became exhausted.

TABLE NO. I /

1874	534,000				
1875	704,000				
1876	1,030,000	15.5	15	21	9
1877	1,070,000	16.5	16	22	0
1878	1,000,000	18,000	17	10	0
1879	1,030,000	17,000	16.5	-	-
1880	1,000,000	14,500	14.5	-	-
1881	1,130,000	22,100	19.5	-	-
1882	1,000,000	19,000	19.0	-	-
1883	1,000,000	14,500	14.5	-	-

TABLE NO. I.

<u>Year</u>	<u>Total Shale mined in Britain</u>	<u>Total Sulphate recovered from Shale</u>	<u>Yield per ton of Shale</u>	<u>Price per ton</u>
	<u>Tons (approx).</u>	<u>Tons</u>	<u>Pounds</u>	<u>£ S.</u>
1869	-	-	-	14 0
1871	-	2,350	-	- -
1873	524,000	-	-	- -
1879	784,000	4,750	-	18 10
1882	1,030,000	5,900	12	21 0
1888	2,070,000	22,100	24	12 0
1894	2,000,000	33,000	37	10 0
1900	2,280,000	37,000	36.8	- -
1905	2,500,000	46,300	41.5	- -
1910	3,130,000	59,100	42.2	- -
1915	3,000,000	58,800	44.0	- -
1920	2,800,000	54,300	43.5	- -

## 2. THE INFLUENCE OF THE MARKET FOR THE PRODUCTS OF THE DESIGN OF OIL PRODUCING RETORTS. (Continued)

In very recent years the value of Sulphate of Ammonia has been generally low and subject to considerable fluctuations, while the imposition of import duties has increased the value of crude oil. The development of the light compression ignition engine for road vehicles has created a demand for a light Diesel oil, in the production of which the crude oil from Lothians shale is particularly suited.

Prompted by those market changes and the rising cost of fuel, stores and labour, retorting research recently carried out has enabled greatly increased throughputs of shale to be handled by modification of existing retort designs and methods of operation. These changes were accompanied by a slight reduction in the Ammonia yield but at the same time have made possible important economies in fuel.



### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850.

#### a. Substances other than Shale

The earliest patents on the production of liquid oils by distillation, specified "Coal" as the raw material, and it was not until 1835 that there is any record of "Shale" being used for this purpose.

The first British patent on the subject was taken out in the year 1681 (No.214) when John Joachim Becher and Henry Serle described - "a new way of makeing pitch and tarre out of pit coale never before found out or used by any other".

In 1694 Martin Eele, Thomas Hancock and William Portlock obtained a similar patent (No. 439 of that year) describing "a way to extract and make great quantities of pitch, tarr and oyle out of a sort of stone of which there is sufficient plenty within our dominion, East and West".

Similarly indefinite as to the raw material of the oil extraction process are the next two patents to be noted, Nos. 405 of 1716 and 587 of 1742. In the first Talbot Edwards craved "especial lycence for sole making of pitch, tarr and oyle from rock or roofe stone by fluxing with fire only". In the second Michael Betton & Thomas Betton described "an oyle extracted from a flinty rock for the cure of rheumatick and scorbutick and other cases". "The material out of which the said oyle is extracted is the black pitchy flinty rock which is commonly found lying next or immediately over the coal in coal mines".

The /

### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850

#### a. Substances other than Shale (Continued)

The exact nature of these "roofo stones" and "flinty rocks" is not certain, although they were probably cannels or coaly shales, but their mention implies a search for oil producing minerals other than ordinary bituminous coal, no doubt with a view to providing an oil more suited as an illuminant than the smoky product distilled from the more common mineral.

The first instance of a description of the apparatus necessary for preparing these oils is found in Patent No. 1015 of 1772 in which Baron Christian Wilhelm Van Haake described a "secret art or mystery in extracting and making from several minerals, compositions called mineral tar and mineral oil". Van Haake then described his apparatus as "a number of iron cylinders" and the process such that "a quantity of such mineral or coal is put therein and a large quantity of common burning coal is put round them and set on fire, which causes a fluid matter or consistence to run or issue from the mineral or coal into a cylinder".

The better known process of Archibald 9th Earl of Dundonald (Patent No. 1291 of 1781) claimed "a method of making tar, pitch and essential oils from pit coal" and described what was practically an internal combustion retort. This consisted in "admitting the external air to have a passage through the vessels or buildings in which the coal is put," "by which means the said coals after being kindled /

### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850.

#### a. Substances other than Shale (Continued).

kindled are enabled by their own heat (without flaming) and without the assistance of any other fire to throw off in distillation or vapour, the tar, oils etc. which they contain, into condensing vessels". The specification makes clear that the process differs from "the distillation of coal in close vessels". Lord Dundonald's process was applied in a plant which was erected at Muirkirk and was in operation till about 1830, producing tar, oil, naphtha and coke.

Early in the 19th century three other patents are to be noted, claiming improvements in the manufacture of tar and oils from a variety of "coals", "bitumens", "peat", "fuccinium", and undefined "mineral substances".

Albert Winsor's Patent No. 2764 of 1804 specified "a metal, brick or earthen stove, oven, retort or vessel", as the retort.

John Denize's Patent No. 2827 of 1805 merely specified "a suitable still", while Patent No. 4029 of 1816 in the name of Daniel Wilson described retorts in the form of horizontal cast iron tubes heated by being built into lime kilns.

Contemporary with the work in England and Scotland on the distillation of coal and associated minerals, peat was being treated in a similar way in several parts of the world, and on the continent of Europe wood and lignite were being used. Solid paraffin was discovered by Christison in Edinburgh in 1830, having been extracted by him from Burma petroleum. Christison gave the name "Petroline" to this newly discovered substance but to Reichenbach is due the better/



### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850

#### a. Substances other than Shale (Continued)

better known term "Paraffin", when, in 1830, he prepared this substance from Beech wood tar.

It is of interest to note that the first British patent on the production of oil from peat granted to Michael Linning in 1837 (Patent No. 7296 of 1837) mentioned that "by heating the peat in a closed vessel or retort, gas, oil, ammonia and materials of which candles may be made" "are produced besides the coke and tar".

In the year 1849 another patent (No. 12436 of 1849) on the distillation of peat appeared in the name of Reece Rees followed in 1850 by another (No. 12990 of 1850) in the name of William Stones. In the former a producer type of furnace appears to have been used and in the latter the peat was compressed and carbonised in "a closed vessel at 700 F". Included in Stones' patent is also the process of distillation of shale and cannel with superheated steam, a point which will be referred to in its proper sequence. The Reece Rees process for peat distillation was tried out at Kildare in Ireland but without much success. Interest in peat distillation was revived by Ziegler who erected plant in the Oldenburg district of Germany in the 13.14. 1890's, but neither this nor a similar project by the same person in Russia was long lived.

Wood was distilled in Norway and Sweden in the 17th century and Lignite was similarly treated in Germany in the latter part of the 18th century. Krunitz described the production of "Rock oil" by the distillation of Lignite in 1788 and since then the industry has developed /



### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850

#### a. Substances other than Shale

developed into a large and important one in Germany.

#### b. Oil Shales as a Source of Oil

In the patent literature of France, reference is made to oil shales as early as the year 1838. In that year Selligue took out French Patent No. 9467 on the production of oil from "bituminous schists" and followed it with additions in 1839 and 1845. Shale oil had however already been made on an experimental scale by Laurent in 15.

1835, utilising the "bituminous schists" of the Autun district.

Selligue & de la Haye enlarged the scale of operations and fractionated the crude Autun oil into light and heavy oils and wax and some of these products were shown by them at the Paris Industrial Exhibition of 17. 1839.

The first two British Patents on oil from shale were also granted to Frenchmen and their patent specifications give a remarkably clear description of the processes of retorting and of the refining of the product.

In 1841 Count de Hompesh obtained British Patent No. 9060 on "Improvements in obtaining oils and other products from bituminous matters and in purifying and rectifying oils obtained from such matters". The raw materials are described as "bituminous schists, shales or slates or other rocks or minerals containing bitumen or bituminous substances". In this patent specification also, a continuous retort is described, of a design which in essential is the /

### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES for OIL PRODUCTION UP TO THE YEAR 1850

#### b. Oil Shales as a Source of Oil (Continued)

the basis of several of the present day low temperature carbonisation coal retorts. This consisted of a horizontal cast iron tube closed at the ends except for shale inlet and outlet ports. The tube contained a close fitting helical screw, rotated continuously by mechanical power and was also fitted with three vapour offlets along its length. As the tube was heated more strongly at the outlet end, and each of the vapour offlets was coupled to a separate condenser, a certain degree of fractional distillation was evidently intended. A retort of very similar design was patented by James Young in 1866. (Figure 44).

The second British patent on shale oil was no less complete in its description of retorting process, retort and purification scheme. The patent was in the name of Michel du Buisson (No. 10726 of 1845) who was associated with Selligie in France. The patent claimed "new and improved methods for distillation of bituminous schists and other bituminous substances as well as their purification". The main feature of the specification was the retort, intended to heat the shale in relatively thin layers and arranged for the introduction of steam which "reduces time of working and increases yield".

The retort consisted of two inverted cast iron cones placed one inside the other and separated by a space of a few inches. The annular cover between the cones was pierced by pipes through which vapours /

### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850

#### b. Oil Shales as a Source of Oil (Continued)

vapours were drawn off and by openings for charging the retort with raw shale. At the apex of the outer cone was a hinged round door for discharge of spent shale. Hot gases from four or more fires in the brick setting heated the outer cone, then passed downwards over the surface of the inner cone before escaping to a central iron chimney. A coil of cast iron piping in the combustion spaces superheated steam on its way to enter the retort at its lowest point. The drawing of the retort accompanying the patent specification is reproduced in Figure I.

The next reference to oil from shale is in the 1850 patent of William Stones (No. 12990 of that year). This patent dealt primarily with the distillation of compressed peat in closed iron vessels but also in a general way covered the distillation of shales and cannels by the passage of superheated steam.

In October of the same year James Young took out his historic patent No. 13,292 which although making no mention of oil shale as the raw material, was very soon applied to this mineral and thereby started the shale oil industry in Scotland. Young's process actually differed little from former patented processes for recovering oil from a wide variety of minerals but lacked the important feature of admission of steam to facilitate distillation, which some other patents possessed.

The patent concerned "Improvements in the treatment of certain bituminous /



3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES  
FOR OIL PRODUCTION UP TO THE YEAR 1850

b. Oil Shales as a Source of Oil (Continued)

bituminous mineral substances and in obtaining products therefrom", and described "the obtaining of paraffine oil, or an oil containing paraffine, and paraffine from bituminous coals" by heating "the coals" in a "common gas retort". The retort was "gradually heated up to a low red heat at which it was kept until volatile products ceased to come off". In operation it was advised that "care must be taken to keep the temperature of the retort from rising above that of a low red heat, so as to prevent as much as possible the desired products of the process being converted into permanent gas".

After carbonising, the coke was withdrawn and the retort allowed to cool "below a visible red (to prevent the waste of the fresh material to be introduced)" and then recharged.

The raw material referred to as "the coals" is parenthetically described in the specification as "usually called parrot coal, cannel coal and gas coal" and the patent covered the use of those coals only, no reference being made to oil shale.

Actually Young experimented with numerous cannel coals from Fife and the Lothians before deciding that the most suitable was the rich Boghead coal from a locality near Bathgate in West Lothian.

Products made by distillation of this coal and subsequent refining of the oil were shown by Young at the Crystal Palace Exhibition in 1851 and were described as being derived from "the cannel coal of Boghead near Bathgate". The growing interest in the production /



### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850

#### b. Oil Shales as a Source of Oil (Continued)

production of mineral oil by distillation of a wide variety of substances is shown by the exhibition at the same time and place of samples of paraffin oil from shale by A. Wiesmann & Co. of Augustenhütte, near Bonn, similar samples derived from bitumen by A. Moreau of Paris and shale oil products by V. Delignon from France. 18.

The plant which Young set up at Bathgate in 1851 was designed to use Boghead coal as its raw material and it was only when the supply became almost exhausted that the true oil shales were used about 1860/62.

The reserves of the Boghead coal or Torbane mineral, ( a name given it by the Lord President of the Court of Session in 1854 during the trial - Gillespie V Russell) were not extensive and indeed were confined to a basin of about 2500 acres in area, with an average thickness of under one foot.

The rapid depletion of the reserves and the rising cost of the mineral made it so scarce and expensive that by the year 1862 it had ceased to be of importance as an oil source and Bathgate works were already retorting oil shale.

Robt. Bell, a Wishaw iron master is usually credited with the realisation of the value of the Lothians oil shale as a source of mineral oil when he discovered large deposits of this mineral at Broxburn while searching for iron-stone in 1859. There is little doubt however that James Young was aware of the existence of the local /

### 3. THE HISTORY OF THE DISTILLATION OF CARBONACEOUS SUBSTANCES FOR OIL PRODUCTION UP TO THE YEAR 1850

#### b. Oil Shales as a Source of Oil (Continued)

local shales and had investigated their possibilities by the year 19. 1856.

The enforced change over from Boghead coal to oil shale enormously increased the reserves of oil, even although the yield per ton of mineral treated was considerably decreased. Whereas Boghead coal yielded from 100 to 120 gallons of oil per ton, the best of the oil shales gave only about one third of this quantity. On the other hand, Boghead coal yielded a negligible quantity of Sulphate of Ammonia as compared with the 35 - 55 lbs per ton which was later obtained with the best design of retorts handling oil shale.

While in the early years of the industry in Scotland a few small operators retorted Boghead coal under licence from Young, the expiry of his patent in 1864 brought a great expansion in the industry, principally in the use of the Lothians oil shales, although cannels and coaly shales continued in use elsewhere, notably in Fife, Lanarkshire and Renfrewshire.

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915.

With the great extension of the mineral oil industry in Scotland in the early 1860's the design of retorting plant became of paramount importance, particularly as the products had now to meet the competition of imported American and later, Russian petroleum.

There ensued a period of about twenty years during which very many operators and inventors proposed a multitude of retorts, many of which were tried out in practice, few successfully. The aims of these widely differing systems of retorting were :-

1. To increase the yield of oil.
2. To improve its quality, i.e., the quantity and quality of the products which could be recovered by refining.
3. To economise fuel and labour.
4. To facilitate operation.
5. To prolong the life of retorts.
6. To increase the throughput of raw material.

About the year 1880 the additional importance of the ammonia yield was realised and there followed the period during which retorts were designed for maximum ammonia as well as oil yield, ultimately with the added complication of mechanical operation.

In very recent years, modifications of established retort design have been made with a view to greatly increasing the throughput with coincident fuel economy.

In order to study these changes in an orderly manner it is necessary because of the diversity of systems of retorting, to have a classification scheme. That most suited to the present study takes as its basis the method of heating the charge in the retorts, and is divided into nine sections as follows :-

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915 Continued.

- a. Horizontal retorts externally heated.
- b. Vertical retorts externally heated.
- c. Inclined retorts externally heated.
- d. Retorts heated internally by (1) Steam, (11) Hot gases.
- e. Mechanical retorts in which the charge was stirred or raked into contact with the heating surfaces.
- f. Retorts in which the oil was distilled off by the sensible heat of combustion of part of the charge in the retort itself, i.e. internal combustion retorts.
- g. Retorts in which the oil denuded shale was used as fuel for heating the retorts, in an external furnace.
- h. Retorts designed to treat the shale in two temperature stages so that a maximum yield of ammonia as well as oil was obtained.
- i. Two Stage retorts (as in "h") designed for mechanical instead of manual operation.

Section a. Horizontal retorts externally heated.

The specification of Young's 1850 patent defined the raw material of the process as "parrot coal, cannel coal and gas coal". The plant required was "a common gas retort" and the pieces of the charge compared in size with "a hen's egg". By the common gas retort was meant the horizontal cast iron circular or "D" sectioned gas retort in use at that time and described in many patents on Gas Manufacture before 1850. In his patent specification Young also stressed the necessity of working at no more than a "low red heat" in order to give the maximum yield of oil and the minimum make of gas. No mention was made of the use of steam as a distillation aid although it was proposed by earlier patentees such as du Buisson.

Despite /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section a. Horizontal retorts externally heated (Continued)

Despite the numerous patents which were taken out prior to 1850, on the production of oil from a variety of minerals, several others appeared after Young's process was in actual operation at Bathgate Works. The first of these was in 1853 when J. Perkins obtained patent protection for "the obtaining of paraffine oil or an oil containing paraffine from bituminous mineral substances found in coal formation and known in their respective localities under the name of basses, black basses, bats, blaes, greasy blaes, shining blaes, coal shales, argillo bitumens and bituminous argils, bituminous sandstones and asphalt coals (not including bituminous coal), yielding bituminous matters by the application of heat". Conventional horizontal retorts were specified and a low red heat advised. This patent was numbered 307 in 1853.

In the year 1856 R.A. Brooman was granted Patent No. 516 which was also very similar to its forerunners. He claimed to obtain by retorting of "bituminous shale, boghead mineral and other similar schistose substances" a number of products including a solvent for caouchouc, an oil for scouring woollen fabrics, illuminating oil, lubricating oil, ammonical liquor, blacks for paints, printing ink and decolourising sugar etc. The sketch accompanying the patent specification shows the "D" sectioned horizontal cast iron retorts mounted in pairs over a common furnace, and the condenser in the form of a coil in a barrel of water (Fig. 2).

In /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section a. Horizontal retorts externally heated (Continued)

In the very early days of the gas industry, operators noting the disagreeable odour of gas made from sulphurous coal, sought to improve this by adding various materials to the charge. Thus in 1806 Jas. Heard and in 1819 Uriah Haddock patented the pre-mixing of lime with the coal.

We find similar early attempts to "purify" oil by the addition of substances to the charge of cannel and shale in the retorts, and much later lime was proposed and actually used with a view to increasing ammonia recovery. In connection with the purification of oil, Paul Wagenmann in 1853 took out Patent No. 2958 on "Improvements in the manufacture of liquid hydrocarbons and paraffin". In essential this was the same as earlier patents except that if the "coals or bituminous slate" were very sulphurous they were to be sprinkled with lime water and dried before retorting. Refining of the oil was described as mixing with a solution of sulphate of iron at 28/30°C. before distilling.

Other two patents of even less promise were those of A.V. Newton (Pat. No. 960 of 1856) and C.M. Kernot (Pat. No. 1117 of 1858). Newton claimed that if the shale or coal in the horizontal retorts was covered by four times its weight of sand, clay, chalk, gypsum, etc., and the distillation carried out very slowly, the vapours rising from the charge were filtered on their passage through the sand etc., and the resultant oil thereby purified. Kernot's method /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section a. Horizontal retorts externally heated (Continued)

method was similar, but in the upper part of the retorts, perforated plates were fixed, and on these were placed "powdered coke and sand in layers, through which the evolved products" passed and were "filtered on their way to the head and hence to the condenser".

The retorts first used at Bathgate Works in 1851 were of horizontal cast iron pattern and of D section. They were of course intermittently operated and were heated externally by coal fires. Much heat was inevitably lost in cooling down of the settings between the withdrawal of the residue and the recharging with fresh mineral. The quality of the oil produced was dependent on the temperature of distillation and in the absence of instruments was therefore largely at the mercy of the firemen.

With the expansion of the industry, horizontal retorts were increased in size and the cross sectional shapes became more diverse. Figures 3, 4 and 5 taken from a Bathgate Works drawing of 1865, show three forms which were in regular use at Bathgate up to that date. These retorts were single ended, i.e. were charged and drawn from one end, while the vapours escaped by a pipe at the opposite end. The smaller retorts, which were either of round, oval or "D" section, were usually cast in one piece, but the larger types often had separate covers. Some of these retorts are shown in Figs. 6, 7 and 8. One of the larger retorts was that devised by T. Bell and of which a number were erected at several small works near Broxburn about /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section a. Horizontal retorts externally heated (Continued)

about the years 1863/1865. It was of rectangular section, 12' long x 3' high and 1' wide, and was fitted with a simple charging hopper. Because of its being mounted on one of its 1' x 12' sides, it was also known as an "Edge" retort. T. Bell's retort was the subject of Pat.No. 2255 of 1863. Fig. 6 shows an "Edge" retort similar to Bell's but with a separate cover and no charging hopper.

Cowan's retort (Fig. 7) was 9' long, 5' 6" wide and 1' 6" high in its greatest vertical dimension. A number of Cowan's retorts were in use at the Arden Oil Work near Airdrie in 1866/70.<sup>20.</sup>

The retort shown in Fig. 8 was also much in favour and in its largest size was claimed to hold as much as 50 cwts of shale, although the usual charge for the less pretentious retorts was from 5 to 8 cwts. These retorts were normally charged by means of a shovel, and the residue withdrawn by an iron "clat". Many devices were tried and some patented, for charging and more particularly for drawing horizontal retorts. One took the form of an open topped scoop-shaped vessel slightly smaller than the retort which was filled with shale and hoisted bodily into the retort, there to remain until retorting was completed. Sometimes charging was by shovel, but embedded in the shale were perforated plates or "clats" attached to chains or jointed rods, which when withdrawn after retorting, ejected the residue also.

J. & T. Bell obtained Patent No. 1073 of 1872 in respect of a mechanically operated discharging apparatus attached to a locomotive. This /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section a. Horizontal retorts externally heated (Continued)

This apparatus consisted of a long bar inserted and withdrawn by means of a rack and pinion on the locomotive. The part of this bar entering the retort carried a number of hinged rakes which folded up on insertion and opened out on withdrawal, thus carrying the shale residue before them. Similar arrangements operated either manually or by machinery were patented by H. Shanks of South Queensferry, and by G. Anderson and J. Buchanan later in the same year (Patents Nos. 1771 and 1768).

The time during which the shale remained in the retorts varied from 16 to 24 hours according to size of retort, temperature etc., but it is understood that even after that period complete removal of oil was not obtained. The yield of oil was poor as compared with even the most primitive of the succeeding vertical retorts, largely because steam could not be usefully injected into horizontal retorts. The yield of ammonia was also very low, although this was not of importance in the early days of the industry. The horizontal retorts taken over when the Broxburn Oil Coy. was formed in 1877 gave an ammonia yield of only 5 to 7 lbs. Sulphate of Ammonia per ton with the Broxburn shale.<sup>21.</sup>

The rectangular or "Edge" retorts such as Bell's were sometimes built in pairs, one on either side of a common fire (Fig. 9) or in long benches with a fire between each pair of retorts (Fig. 10). This latter arrangement was the subject of Patent No. 2255 of 1863.

The /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section a. Horizontal retorts externally heated (Continued)

The "D" shaped, oval and round horizontal retorts were usually built in oven shaped brickwork settings over a common coal furnace, the number of retorts to each setting being either 3 or 5. Three retort settings are shown in Figs. 11 and 12, while Fig. 13 is a reproduction of a Bathgate Works drawing of 1867, showing five 9' x 2' x 1½' oval retorts in a single setting.

One of the last installations of horizontal retorts was made at Bathgate Works in 1872. 27 Sets, comprising 135 large cast iron retorts were erected, each retort being of oval section about 3' x 2' x 12' long. Each set consisted of five retorts placed round a common furnace as in Fig. 13. They were worked intermittently, were charged by shovel, and were closed at the charging end by an oval cast iron door. Before charging, an oval perforated iron plate attached to a long rod with an eye on the outer end was pushed into the retort. To draw the retort, the cast iron door was opened and the eye on the end of the rod coupled to a portable winch which was then used to draw out the perforated plate, and with it the spent shale. A horizontal rail fixed at some distance from the retorts and running the whole length of the bench was used as an anchor for the drawing gear, while a line of rails in front of the bench permitted of hutches being brought in to receive the discharge from the retorts.

Section /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts.

Within two years of the starting of Bathgate Works, Jas. Young erected an experimental setting of three vertical tubular cast iron retorts. The increased yield obtained from these retorts and the relative ease and cheapness of their operation led to the extensive use of the vertical form at Bathgate and many other works in Scotland. The extent of this increased yield which was soon found to be the result of the change over from horizontal to vertical retorts, particularly if steam was admitted to aid distillation, is indicated by the results of tests carried out by G.T.Beilby at Oakbank Works in 1869. Over a long period, the Broxburn shale seam from Mid Calder area gave a yield of 24/25 gallons of oil per ton in small horizontal retorts and 32/33 gallons per ton in vertical retorts. <sup>22.</sup>

During the 'sixties and early 'seventies, much controversy raged around the relative merits of horizontal and vertical retorts, for although the vertical retort was admitted to be cheaper to operate and to give a larger yield of oil, this oil suffered a greater loss on refining and gave a smaller yield of illuminating oil than did oil from the same shale distilled in horizontal retorts. The oil from the vertical retorts also contained more paraffin, which in the very early days was of little value, and indeed was at first burned or tipped out on a waste heap. As an example D.R. Steuart reported that in the "Edge" type of horizontal retort, the /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts (Continued)

the Broxburn seam at Broxburn gave 27 gallons of crude oil containing  $51\frac{1}{2}\%$  of burning oil and naphtha, 5% medium oil, 10% of light lubricating oil, and only 5% of crude paraffin scale.<sup>23.</sup> In well operated vertical retorts with ample steam, the same shale would give up to 35 gallons of oil containing about 35% of burning oil and naphtha but as much as 12% of crude paraffin scale.

For these, among other reasons, the horizontal retort continued to be built long after the introduction and improvement of the vertical. Thus, in 1872, there were erected at Bathgate 27 sets of intermittent horizontal retorts already described, although by that time only vertical retorts were in use there. These particular retorts were in operation for a few years only.

With the realisation of the value of solid paraffin and the growing demand for Sulphate of Ammonia, to the production of which the horizontal retort was unsuited, the vertical retort became universally approved, and the existing horizontal plant was gradually demolished as new vertical plant was built.

Reference to the patent literature gives very little indication of the great development which actually took place in vertical retort design. In the expansion of the industry in the 'sixties and 'seventies individual operators erected their own modifications of the simple tubular form, and of these retorts which were patented, few if any were actually tried out and only a very few were important /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts (Continued)

important as contributions to the evolution of retort design generally.

It is now impossible to obtain much information about the retorts used in the numerous small works which came into existence in Scotland about this time. In the first 45 years of the industry a total of 117 works were built although few operated for more than a year or two and some only for a few months. In the year 1860 a maximum of 67 works were in operation but the number had fallen to 19 by 1880 and to 12 by 1895.<sup>24.</sup>

In the study of the many variations in the design of vertical iron retorts it is convenient to classify them into four main groups as follows:-

1. Vertical cast iron retorts of more or less tubular form sealed at the base in water pans.
2. Retorts of similar shape but arranged for dry discharge of the residue.
3. Retorts in which the tubular form was considerably departed from.
4. Retorts not included in the first three groups.

##### Group I. Vertical Retorts sealed at the base in water pans.

Jas. Young erected the first set of three experimental vertical iron retorts at Bathgate Works about 1853. They were parallel sided cast iron tubes about 18" diameter and 10' long. The three retorts were set up in a chamber which was heated by hot gases from a coal fired furnace. The tops of the retorts were surmounted /

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
FROM THE YEAR 1850 TO THE YEAR 1915

Section b. Vertical Retorts

Group I. Vertical Retorts sealed at the base in water pans  
surmounted by small hoppers and the bottoms were sealed in rectangular cast iron troughs filled with water, through which the spent material was raked out at half hourly intervals. One end of each trough was sloped to make this operation easier.

The raw material was Boghead coal, but owing to its swelling nature, trouble was experienced with the sticking of the charge in the retorts and frequent use of long pokers was necessary. In consequence, Young had some tapered retorts made and mounted in the usual way with top hoppers and water seal troughs. In each retort a vertical helical screw was fitted, the shaft of which was extended out through the top of the hopper so that it could be slowly turned by mechanical power. The withdrawal of residue was by hand as before, and the purpose of the screw was simply to prevent the charge sticking.

These retorts were quite successful and were in use for eight years although the internal screw was not used during the whole of that period, probably owing to the fact that Boghead coal was then being replaced by oil shale as the raw material.

Historical Note. The exhaustion of the reserves of Boghead cannel coal in the early 'sixties led to the building of the first large shale retorting plant at Addiewell where the first oil was run in 1866. Although the building of Addiewell Works was started by Jas. Young /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group I. Vertical Retorts sealed at the base in water pans

Young, the unfinished plant was taken over along with Bathgate Works by Young's Paraffin Light & Mineral Oil Co.Ltd. in 1865, a year after the expiry of Dr Young's patent. Bathgate Works was shut down (except for acid production) in the year 1887, but retorting had stopped in 1884. From 1864, crude oil was brought into the refinery to augment the make of the retorting plant, and from 1884 to 1887 only bought in oil was refined.

Perhaps one of the most important improvements in the working of vertical iron retorts was the introduction of steam to the base of the column of shale during retorting. It is commonly believed that Jas. Young introduced the use of steam for this purpose about or before the year 1860. He is also reported to have stated that by the introduction of steam to vertical retorts the yield of oil from Boghead coal was increased from 80 to 120 gallons per ton.<sup>25.</sup>

The principle of steam injection during retorting was however not new, as du Buisson in his patent No. 10726 of 1845 claimed that steam introduced into his cone shaped retort reduced the time of working and increased the yield. In 1853 also Wm. Brown's

Patent No. 92 dealt with the subject of "distilling coal and other bituminous substances in conjunction with steam at a dull red heat". The patent specification makes it clear that the retort was a closed one, heated externally and that steam was passed through during distillation./



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

Group I. Vertical Retorts sealed at the base in water pans.  
distillation.

Following the expiry of Young's patent in 1864 and with the opening up of the shale areas, the vertical form of cast iron retort underwent intensive development in several works in Scotland and even 15 years later retorts were being erected (notably at Oakbank Works by G.T. Beilby) which had the essential features of Young's early designs.

Following Young's experimental vertical retorts which by their use of the bottom water seal fall into Group I. of the present classification, many variations were tried out. One of the first and perhaps the most important was that known as the "Kirk" retort, named after Young's engineer at Bathgate. The first of these retorts were erected at Bathgate before 1860 and they were later used (often with considerable modification) in nearly all the oil works of importance in Scotland (Fig. 14). The "Kirk" retorts were bottle shaped in front elevation and were usually of a flattened oval cross section about 24" x 14" at the widest part, but round sectioned ones were also made about 24" in diameter. The length was from 8' to 10'. The purpose of the flattened cross section was to expose more surface to the furnace gases and to reduce the distance from the hot retort walls to the centre of the charge. Sometimes the upper small diameter parts were of circular section and the lower parts elliptical. The vapour pipes were attached to the /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts.

##### Group I. Vertical Retorts sealed at the base in water pans

the narrowest part of the retorts. As originally designed the "Kirk" retorts were mounted in sets of 6 or 8 retorts in line, although the first was the more usual arrangement as in Fig. 15. Heat was supplied by a coal fired furnace in the middle of each set and the furnace gases passed right and left round each group of retorts. Heating was in three horizontal passes so that the lowest portions were exposed to the highest temperatures. In order to prevent overheating of the lowest parts of the retorts it was common practice to protect them by firebrick tiles. This, however, often had the effect of transferring the trouble to the still unprotected middle parts. The raw shale was shovelled into tall hoppers at the top of the retorts. These hoppers were fitted with bells in the upper portions and so arranged that the bells could be lowered by long permanently attached levers. The lowest part of the retort below the heated section did not normally dip into the water seal, but was often bolted to a flanged cylindrical casting or "nose piece" which did so.

Steam was introduced into the base to facilitate distillation and to remove the products rapidly. Every hour some spent shale was withdrawn from the water trough in such quantity that at the end of three hours, 4 cwts. of raw shale could be charged to the top hopper through the bell. The throughput of the retorts was thus /

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
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Section b. Vertical Retorts

Group I. Vertical Retorts sealed at the base in water pans

thus about 32 cwts per day. Their capacity was 20/22 cwts so that the shale took from 15 to 16 hours to travel down the whole length of the retort. The coal consumption was as much as 5 cwts per ton of shale distilled.

The lowest parts of these vertical iron retorts often suffered severely from overheating because of careless firing and from attempts to increase throughput. Bulging and "sitting down" resulted and a life of from two to four years was considered satisfactory, although many retorts failed after as little as six months' use.

When Addiewell Works started operations in 1865, "Kirk" retorts were used exclusively, these particular ones being round at the top and of elliptical section lower down. Each retort, of which Addiewell had six to each set, was about 10' high. The throat at the vapour offlet was 1' 3" diameter and the greatest width in the lower elliptical portion was 2' 2". "Kirk" retorts at Addiewell were in use until Henderson retorts were introduced after 1874. For a time the gas from the "Kirk" retorts at Addiewell was sold to the West Calder Gas Coy.

The "Kirk" or bottle shaped retort was often considerably modified both in shape and in the method of mounting it in the brickwork. The extreme bottle shaped retort became more nearly a tapered retort and instead of being mounted in line they were grouped together in greater numbers than the original six or eight.

Consequently /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group I. Vertical Retorts sealed at the base in water pans

Concurrently with these modifications to an established design, true tapered retorts were being built either of round or oval section. The retorts were grouped round one or more open coal fires, there being no standard arrangement but the ultimate aim was probably to heat as many retorts as possible from a single furnace. Thus we find as few as four and as many as sixteen retorts to one fire.

Various lengths of retort were in use, 11 and 12 ft retorts being most common and 15 ft retorts less usual. Increased length was found to give an increased yield of oil and ammonia. The retort wall was about 2" thick, but owing to there being more wastage at the lower and hotter parts, these were often made thicker than the upper parts. The lower ends of the retorts usually dipped into shallow water seal troughs as in the original "Kirk" retorts. Sometimes each retort had its own trough, but often a number of retorts stood in a large trough. The troughs also varied in design some being iron castings and others were made of wrought iron plates riveted together. Usually they were single-ended, i.e. the spent shale was drawn to one side of the bench only, but some were made with both ends sloping so that spent shale could be drawn out from either side. One of these large double-ended troughs, measuring 8' long, 7' wide and 2' deep, lies beside the Uphall/Hopetoun railway /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group I. Vertical Retorts sealed at the base in water pans

railway near Ecclesmachan in West Lothian and its size can be judged from the fact that it has for years been used as a shelter by railway surfacemen.

Figures 16 to 27 illustrate typical arrangements of vertical iron retorts which were in use at Bathgate and Addiewell works between the years 1862 and 1880.

A setting of modified "Kirk" retorts is shown in Figs. 16, 17 and 18. This setting was 16 feet long and 10' 3" wide and contained 12 retorts 6' 9" long measuring 18" x 10 $\frac{1}{2}$ " at maximum cross section. Each pair of retorts was served by a single large water seal pan and the whole setting was heated by two coal fired furnaces, one at either end. Figs. 19, 20 and 21 show an early setting of four simple tapered round section 10 foot retorts with one furnace only and a water seal pan to each retort. Figs. 22, 23 and 24 show an interesting setting of twelve round section tapered retorts, each with its own water seal pan. From a centrally placed furnace hot gases passed right and left round the two groups of six retorts before escaping through two main flues.

Finally, oval section tapered retorts are shown in Figs. 25, 26 and 27, this particular setting having ten 15 foot retorts of 2' 2" x 1' 3" section compactly grouped round one furnace and each pair mounted over a large water seal pan.

While /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group I. Vertical Retorts sealed at the base in water pans

While several works retained the original form of "Kirk" retort, development work on longer retorts was carried out principally at Uphall, Addiewell, Oakbank and Dalmeny works. Prompted by the proved fuel economy of the Henderson 1873 retort and its adoption at Broxburn, Burntisland and Linlithgow works, further improvements were made elsewhere in the conventional vertical iron retort with a view to improved fuel economy. At Oakbank works in 1878/1880 and about the same time at Dalmeny, Addiewell and Uphall, existing vertical retorts were improved by clearing away all superfluous brickwork and flues and permitting the retorts to be heated in large open chambers. The retorts were exposed to a lower temperature than formerly, and although the yield of ammonia fell because of this, the throughput of shale was maintained, the quality of the oil improved, and the coal consumption reduced to  $1\frac{1}{2}$  cwts per ton, while at the same time the life of the retort was lengthened. <sup>26.</sup> One form of these improved Oakbank retorts, of 1878/80 is shown in Fig. 28. The retorts were about 20 feet long and each group of 8 was heated by a single centrally placed furnace. The much improved oil resulting from the lower and steadier distillation temperature encouraged Beilby at Oakbank to build larger diameter retorts with as many as 16 in a single oven. No advantage resulted, however, and the last of the vertical iron retorts there were pulled down in 1886.

Before /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group I. Vertical Retorts sealed at the base in water pans

Before leaving this group of retorts, it should be recorded that when Beilby was improving his vertical iron retorts in the years around 1880, he conceived the idea of heating them with coal gas from a separate gas plant. Thus in 1883 there was erected at Oakbank a set of four firebrick Grouven-Young-Beilby retorts, externally heated and fitted with air and steam injection pipes. The coal was completely gasified and ammonia recovered to the extent of 90 to 100 lbs of sulphate per ton, while the gas was supplied to two settings each of 16 vertical iron retorts to replace coal fires which had formerly heated them. It is questionable whether the arrangement ever had a full trial as the vertical retorts were abandoned soon after.

In withdrawing the spent residue from all forms of vertical water sealed iron retorts a small bladed steel shovel was almost invariably used, but there are records of two attempts to mechanise the operation of withdrawal and thereby operate the retorts continuously. The first of these was in connection with Jas. Young's early tapered iron retorts which had an internal screw to agitate the charge of Boghead coal. For a time these were fitted also with a sloping helical screw in the water trough at the base of each retort. Results showed that the device did not greatly reduce the manual labour expended in handling the residue and that the /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group I. Vertical Retorts sealed at the base in water pans

the cost of operation and repair of the gear more than offset any advantage gained by its use.

Young's engineer Kirk patented in 1869 (Pat. No. 3224 of 1869) an oscillating form of extraction gear for use with vertical retorts having double sided water seal pans. It is not known however if this mechanism was in actual operation. It is illustrated in Fig.29.

A characteristic of the "Spent shale" from all vertical water sealed iron retorts was its black, soft friable nature. Pieces could thus be easily broken across the bedding places by hand. Its high free carbon content and porosity suggested its use as a decolorising agent, and at Addiewell Works it was for a time used for this purpose in paraffin wax refining, with what success it is not known.

##### Group 2. Retorts with Dry Discharge of the Residue

While the relatively short bottle shaped retorts were invariably water sealed at the base this was not true of the longer and smaller sectioned retorts. Many of these were mounted in brickwork settings so that the residue could be drawn out through rectangular iron doors on the lower parts of the walls of the settings and communicating with small brick chambers below the retorts.

At Addiewell and Uphall Works a number of this type of retort were /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group 2. Retorts with Dry Discharge of the Residue

were erected about 1870 and were in use up to about 1890. Fig. 30 shows a setting of Uphall Works retorts 15 feet long and about 14" diameter. They were mounted in sets of 8 and the rectangular cast iron doors for the withdrawal of the residue were about 3 feet above ground level. Dry discharge retorts were worked in a similar manner to the more usual water sealed type in that partial discharge was followed by charging of raw shale.

Another instance of a cylindrical iron retort with dry discharge was that known locally as the "Mollocher" and of which a bench was erected at Oakbank Works in 1872. In the "Mollocher" retort the spent shale outlet did not communicate with a brickwork chamber but was cast integrally with the retort itself in the form of an enlarged curved chute which formed the base of the retort and which facilitated the withdrawal of the residue. Distillation was downward and shale was prevented from entering the vapour pipe by a perforated iron plate placed in the curved portion of the retort. It is illustrated in Fig. 31.

##### Group 3. Vertical iron retorts not of tubular form

In order to increase the capacity of the vertical iron retort without increasing its diameter, the thin oval bon shaped retort was developed between the years 1867/72. William Young devised and built a large number of retorts of this type notably at Oakbank, Straiton /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group 3. Vertical iron retorts not of tubular form

Straiton and Walkinshaw Works. These retorts had a flattened oval cross section so that at no point was the centre of the charge more than a few inches from a heated wall. The height was only about twice the greatest width and they were cast integrally with large dry outlets for the spent shale. Operation was intermittent in that the retorts were charged, heated, discharged and recharged. Distillation was downwards, the vapour pipe being connected to the bottom of the discharge chute while steam was admitted to the upper part of the retort. Because of their narrow width, they were easily built in long benches back to back.

One such retort about which we have particulars was that erected by the Midlothian Oil Company at Straiton in 1872 and shown in Fig. 32. It was only 12" wide from wall to wall but was 10 ft high and 5 ft broad. A retort of similar shape had already been associated with the name of W. Young in the Young & Brash internally heated retort of 1867, and in 1880 we again find this shape appearing in the retorts erected by W. Young at Straiton, this time adapted to utilise the spent shale as fuel. These two retorts will be described in sequence.

A narrow sectioned retort similar to W. Young's was that devised by J. Findlay and W. Jack and granted Patent No. 930 of 1875. The sweeping outlet chute shown in Fig. 33 is notable as well as the /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group 3. Vertical iron retorts not of tubular form

the multiple exit pipes for the vapours. There is no record of this retort having actually been used in Scotland.

##### Group 4. Unusual forms of Vertical Retorts

The only one of which we have any record as having actually been used in Scotland was a large all brick retort erected by Jas. Young and D.J. Kenelly at Bathgate Works about 1873. It was built entirely of brickwork instead of cast iron and the total height of the building was 25 to 30 ft. The internal diameter was about 3 ft. The retort was operated semi-continuously and the spent shale was withdrawn through a cast iron door about 3 ft above ground level. Little information is available about the working of this retort of which only one was built.

Another all brick retort although not strictly of vertical form was patented by Jas. Young in 1868 (Pat. No. 1481) and may with convenience be described at this point. It was of a low bee-hive shape with a thin brickwork bottom. A coal furnace heated this bottom directly, then the hot gases passed through the flues in contact with the dome before escaping to atmosphere. The retort was charged from an opening on the top of the dome and drawn through a lower side opening. Some return shale gas was passed into the space above the shale charge "to displace newly formed oil vapours". The retort is illustrated in Fig. 34.

Among the more unusual patented vertical iron retorts, the following /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group 4. Unusual forms of Vertical Retorts

following are of interest :-

In 1862 T. Bell (Patent No. 574) described a vertical annular retort heated by two furnaces, one of which supplied hot gases to the central internal flue and the other to a zig-zag flue system round the outer wall of the retort.

A. Craig in 1863 was granted provisional Patent No. 2812 for a vertical annular retort heated on the outside only. The central tube was perforated and was cooled by water pipes placed therein so that vapours leaving the retort by the perforations were condensed at once.

In 1865 A. Craig obtained provisional protection (No. 2544) for a similar retort in which the central tube was replaced by a column of iron rings between which the vapours escaped to the condenser.

A large diameter, but relatively short vertical iron retort was patented by G. Walton in 1865 (No. 1361). This had a vapour outlet at the top, but a large cylindrical cage in a central position in the retort permitted only a thin layer of shale next to the heated walls. It is illustrated in Fig. 35.

In the early days of the industry, the distillation vapours from the retorts along with the steam injected to them passed over to the condensers unaided. In 1866 J. Harris was granted Patent No. 2847 /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section b. Vertical Retorts

##### Group 4. Unusual forms of Vertical Retorts

2847 in respect of the principle of drawing a partial vacuum on the retorts by means of "a pump or other exhaust apparatus worked by steam or other motive power".

Although the classical work of Beilby & Young on the recovery of ammonia from shale was not commenced until after 1870, it is interesting to note that the subject occupied the attention of inventors at an even earlier date. Thus, in 1862, W.J. Cooper patented the principle of mixing lime with nitrogen bearing minerals before retorting, to increase the ammonia yield. (Patents Nos. 2611 and 5713).

In the early 'eighties, a small work was started at Seafield (West Lothian) where the shale was pulverised, mixed with damp pulverised lime and pressed into bricks. The wet bricks were then stacked in a closed chamber and heated, slowly at first to distil off the oil and then at a higher temperature with admission of air to burn out the fixed carbon and leave a light red brick. Needless to say the process was unsuccessful.

##### Section c. Inclined Retorts

Probably owing to the intensive development of vertical retorts, inclined retorts were little favoured for the distillation of shale. Patent No. 1138 of 1858 granted to W. Clark described a simple inclined retort for distilling peat, but the retort devised by /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section c. Inclined Retorts

by R. Griffiths (Patent No. 2080 of 1863) was actually used at the Kirkwood Oil Work, Coatbridge, for distilling a coaly shale mined there. In the year 1866 there were 109 of these retorts at Coatbridge, but they were out of use by 1878 (Fig. 36). So far as is known these were the only inclined retorts ever used in Scotland for producing oil. They were about 35 feet long and 4' x 1' in cross section, constructed of cast iron built into brickwork. The lower part of the 30 foot inclined retort was extended to "form" a horizontal discharge section about 5 feet long, separated from the retort proper by a movable damper or drop plate and closed at the outer end by a removable cast iron door. The furnace was built under the horizontal portion, but flues therefrom carried the hot gases upwards under the inclined retort and back down over it to the chimney built directly over the furnace. Distillation products were drawn off from several points in the inclined section of the retort. Operation was semi-continuous in that once the drop plate was lowered, the residue was raked out from the horizontal portion of the retort, the discharge door shut, the drop plate raised and fresh charge added at the upper end after opening the upper door.

##### Section d. Retorts heated internally by (1) Superheated Steam

The earliest British patent on retorting by superheated steam was No. 12,990 of 1850 in which William Stones proposed to distil "bituminiferous, carbonohydrous products from shale or schistus or /

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
FROM THE YEAR 1850 TO THE YEAR 1915

Section d. Retorts heated internally by (1) Superheated Steam  
or swine stone or asphaltum or mineral pitch or cannel coal", by  
means of "superheated steam in lieu of carbonising or distilling  
by fire".

A more concrete proposal was that of E. Lavender who described  
a superheated steam retort for distilling "Boghead or other coal".  
(Pat. No. 2350 of 1857). This retort was a horizontal cylindrical  
cast iron vessel clothed in brickwork and fitted with an end charg-  
:ing door and vapour offlet pipe. It differed from the usual cast  
iron horizontal retort in having a perforated false bottom. The  
broken coal was supported by this false bottom and once the charging  
door was closed, superheated steam entered the retort through jets  
placed along the bottom and under the perforated plate.

There followed in 1865, Patent No. 1553 in the name of  
J. Howarth whose retorts were closed vertical iron cylinders fitted  
with top and bottom doors and top vapour offlet pipes. The retorts  
were mounted in pairs over a common furnace from which two flues  
extended and in which were placed one piece cast iron superheaters,  
one below each retort, and from which hot gases rose to surround the  
retorts themselves. The superheated steam entered each retort from  
the bottom and distillation products made their exit at the top. A  
setting of two retorts is shown in Fig. 37.

What was really an adaption of this vertical form of retort  
to continuous operation had been already patented by Jas. Young in  
1861 /

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
FROM THE YEAR 1850 TO THE YEAR 1915

Section d. Retorts heated internally by (1) Superheated Steam

1861 (Pat. No. 486 of 1861). It consisted of a circular group of four sided vertical chambers each fitted with charging and discharging doors and easily movable inlet and outlet pipes (Figs. 38 and 39). The superheated steam from an external superheater passed through the chambers in series so that in the first one or two oil was being distilled off, and in the last the shale was being heated only and would condense some of the oil distilled from the hotter chambers. The gas and vapours from the coolest chamber passed to a condenser and oil condensing in the intermediate chambers was run off through liquid seals. After exhaustion of the hottest chamber, it was disconnected, the superheated steam turned into the next chamber in series and a new freshly charged chamber coupled up at the cold end and to the condenser, so that the process was practically continuous, one chamber always being off for discharging and recharging.

It is also known that in the early "sixties", Jas. Young was interested in an adaption of the conventional intermittent horizontal retort for use with superheated steam. A series of models is in existence, which belonged to Jas. Young, showing various modifications of his retorts, but no mention of it can be found in the patent records. The models show settings containing one or more large horizontal "D" sectioned cast iron retorts mounted over a larger number of smaller ones, all heated by a common coal furnace. Each /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section d. Retorts heated internally by (1) Superheated Steam

Each large and small retort is divided by a central horizontal close fitting plate with a hole at the inner end. The lower and smaller retorts are connected in series to form steam superheaters and the superheated steam is passed into the lower part of the large retort or retorts charged with shale. The steam after passing through the retort in two passes leaves by a vapour pipe at the outer end, carrying off oil vapours to the condenser.

There is no documentary proof however that either this or any other superheated steam retort was ever in use for distilling shale in Scotland. The patent literature however records that intermittent interest was taken in superheated steam retorts for shale distillation up to the year 1884.

In 1869 J. Townsend obtained Patent No. 600 for a simple vertical iron retort into which superheated steam was passed at the top. The bottom outlet pipe was fitted with a loaded valve so as to maintain a pressure of 10 to 20 lbs per square inch on the retort. The steam temperature was given as 600 to 1000 F. and the condenser for the steam and products was divided into sections each maintained at different temperatures to give fractional condensation.

Not until 1882 was this type of retort again in evidence, this time intended for the distillation of Kimmeridge shale. This patent, No. 3792 of 1882 by E.K. Mitting does not strictly fall under this classification as it was externally heated also. It was /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section d. Retorts heated internally by (1) Superheated Steam

was a vertical iron cylinder arranged for downward distillation, but it was notable in that the superheater tube was wound spirally round the retort itself and heated by the furnace which heated the retort.

W. Crossley's retort of 1883 (Pat. No. 2149) differed from its predecessors in the method of superheating the steam. The retort itself was the usual vertical iron cylinder with top charging hopper and bottom outlet for the residue. The superheater was of chequer brickwork heated intermittently by gas from the retorting of the shale in the retort above.

The last superheated steam retort to be described was that patented by B.T.B. Mills in 1884 (Patent No. 69,995) and shown in Fig. 40. It was the usual cast iron vertical cylinder, this time with a top vapour off-take. Steam was superheated to 932-1472<sup>0</sup> F. in a horizontally placed cast iron coil, and passed into the retort through a perforated pipe. The spent flue gases from the superheater furnace passed round the retort before reaching the chimney.

##### Section d. Retorts heated internally by (2) Hot Gases.

Many of these were very similar to the steam heated retorts in principle and construction but unlike them a considerable number were for a period in use in the Scottish oil industry. The heating agent might be either the hot products of combustion or permanent gas heated in a coil or heater external to the retort.

The /

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
FROM THE YEAR 1850 TO THE YEAR 1915

Section d. Retorts heated internally by (2) Hot Gases.

The first retort of this type to be described in the patent records was that devised by Jas. Young in 1864. The heating agent was hot combustion gases and Figs. 41 and 42 show that apart from the fact that the chambers were of circular instead of four sided section, the retort was identical with his steam heated retort of 1861.

In 1864 also, W. Cormack took out a provisional patent (No.1368) on the general principle of lowering the temperature of retorting of solids or the distillation of tar by the passage of "a jet or current of air, steam, gas or vapour, either singly or combined, above or near the surface of the substance undergoing distillation". "The resulting vapour and gases might be employed along with steam, etc. in succeeding retorts, and if desired might be superheated."

Patent No. 2484 of 1864 granted to J.G. Beckton described a line of vertical cast iron retorts heated both externally and internally by hot combustion gases passed through perforations into the retorts themselves. An exhaustor was specified to carry out this modified method of operation, and it is interesting to note that the retort covers were water sealed and the bottoms fitted with "conical plates" opened by steam.

In the following year (1865) Jas. Young obtained provisional protection (No. 571) for the distillation of bituminous substances "in a vertical chamber or vessel by forcing or drawing through these the /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section d. Retorts heated internally by (2) Hot Gases

the heated products of combustion of coke or other fuel".

In the search for a method of distillation of Scottish shale which would give a better oil than that produced by the existing vertical iron retorts, W. Young and P. Brash during the years 1865/7 experimented with retorts internally heated by hot distillation gases. Thus in 1866 Pat. No. 1278 was granted W. Young and P. Brash on the reheating and circulating through retorts "of hydrocarbon distillation vapours which are condensed only with difficulty". In the same way the gases from the subsequent distillation of the oil could be heated and passed into the still from which they were produced.

In the following year (1867) a retort specially designed to utilise this principle was brought out by them and was granted Patent No. 650. The retort was vertical and of a flattened elliptical section of large area in relation to the height. It is shown in cross section in Fig. 43. It was coal fired, two retorts to a single fire but was constructed with a double wall. Distillation was downward and the spent shale was withdrawn by hand through a simple cast iron door. Incondensable return gas from the distillation of the shale entered the lowest part of the hollow retort wall and was superheated in its passage up and around the space to the top of the retort, where it entered the retort proper, passing down through the shale to the outlet pipe. The heating of the shale was thus largely by heated gas. The retort was intermittent in operation /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section d. Retorts heated internally by (2) Hot Gases.

operation. They were set one on either side of a common coal fire and the hot combustion gases travelled round the outside of the gas jacket before passing to the chimney. A bench of these retorts was erected at Oakbank in 1871 and continued in operation for several years. An excellent oil was produced, but the yield of ammonia was very low, only 4-5 lbs of Sulphate per ton being obtained. The high first cost of the retort, trouble with carbon deposit in the double wall space, high fuel costs and low ammonia yield caused their abandonment. In the Scottish industry, the method of distilling shale by passing through it heated gases or steam fell into disuse with the abandonment of the Young and Brash retorts but in 1883, N.M. Henderson re-introduced it in his proposal for a system of all brick retorts designed to distil shale in two stages for maximum recovery of ammonia as well as oil (Page 105).

Internally heated retorts however continued to appear in the patent literature for some time. In 1871, J. Church of Glasgow patented an elaborate arrangement (No. 355 of 1871) consisting of a gas producer and an oven in which the gas was burned, and a series of large vertical brick retorting chambers through which the hot combustion gases passed upwards. The plant also included a waste heat boiler, the steam from which was intended to operate jets at various points to direct the gases through the various flues.

The general principle of retorting of shale and coal by the passage /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section d. Retorts heated internally by (2) Hot Gases.

passage of hot combustion gases was again provisionally patented by A. Munro in 1872 (Prov. Patent No. 938) and in 1880 J. Imray was granted provisional Patent No. 3218 for retorting of coal in a moderately heated retort through which was circulated some of the permanent gases from the distillation itself.

Finally we find that in 1906 C.A. Allison of the American Chemical Education Co. obtained British Patent No. 11,925 for a retort to handle coal, shale, peat or lignite for the production of oils. The charge was placed in a removable cage of trays in a cylindrical retort heated externally by two fires. The hot combustion gases after heating the outside of the retort passed into it at the top at 700/800<sup>0</sup> F. and hence down through the trays before escape at the base of the retort and to the condenser.

##### Section e. Mechanical Retorts.

Between the years 1860 and 1880 proposals for a very large number of mechanical iron retorts appeared in the publications of H.M. Patent Office. While a few were intended for the distillation of bituminous coal, bones, sawdust etc., the majority were oil producing retorts, with oil shale or cannel coal as the raw materials

Generally these mechanical retorts were continuous in operation and the purpose of them all was to agitate the charge and thus to bring it into intimate contact with the heated surfaces. It is probable that some were designed for the Cannel Oil Industry which flourished /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts.

flourished in North Wales and Staffordshire in the 'sixties and 'seventies, but unfortunately there is no documentary evidence in existence which gives information about the retorts in use there. <sup>27.</sup>

In the case of the Scottish Shale Oil Industry, it is generally understood that mechanical iron retorts were tried out in a number of works, but details are available to-day of only two which are known definitely to have been in use, one at Bathgate and another at Broxburn.

Although mechanical retorts were not widely used for oil production, most of the designs of 1860/1880 have in recent years been applied to the low temperature carbonisation of bituminous coal in various parts of the world.

As early as 1815 Samuel Clegg described in Patent No. 3968, a continuous mechanical retort for coal gas production. This consisted of a closed flat circular box 12 feet in diameter and heated strongly at one side only. The coal was contained in flat open iron boxes fixed to radial arms. With the rotation of the radial arms the boxes of coal were slowly brought into the distillation zone and thereafter slowly removed to the discharge position.

Ben Simmon's Patent No. 7023 of 1836 described a rotating cylindrical iron retort, a form which was to engage the attention of many inventors in later years.

The /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

The fixed cylindrical iron retort with a rotating internal screw was also proposed before the establishment of the shale distillation industry in Scotland.

The important patent of Count de Hompesch (No. 9060 of 1841) for the production of oil from "bituminous schists, shale or slates" specified a retort of this type. Hompesch's retort was fitted with three vapour offlets connected to separate condensers, and the heating furnace was so arranged that the shale inlet end was heated to a lower temperature than the discharge end.

In 1866 Jas. Young patented an almost identical retort (Pat.Nos 625 and 992) and this it is understood was for a time in use at Bathgate Works. The retort is illustrated in Fig. 44.

Among the few vertical screw operated retorts was that proposed by W. Ziervogel (Pat. 2487 of 1858). This was a long vertical cast iron cylinder heated externally by hot gases in spiral flues. In the vertical axis of the retort was slowly rotated a large diameter hollow screw through perforations in the middle of which vapours escaped to a condenser. The bottom of the retort could be fitted with reciprocating plates or a screw arrangement for extracting residue.

In the following year F.C. Bakewell proposed an externally heated rotary horizontal retort, and obtained Patent No. 1699 of 1859 (Fig. 45). The vapours passed out through the hollow driving /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

driving shaft, but the operation of the retort appears to have been intermittent.

Other rotary and screw operated retorts came later, but in 1862 W.M. Williams obtained Patent No. 1940 for a continuous retort of unusual construction as shown in Fig. 46. In this retort, the charge (coal or peat) was filled into flat open boxes or cages, which were pushed at intervals into the reverbatory retort so that they were heated from above and the distillation products escaped downwards into a space below the boxes and hence to a condenser. The admission of a charged box at one end displaced a spent box at the other end, and to permit of this being done, slides or dampers were raised at each end before a movement was made.

This retort and another devised by Danchell in 1870, using circular drums instead of boxes, were surely the forerunners of the modern tunnel kiln retort used in Esthonia.

From 1864 to 1866 a number of mechanical shale retorts were proposed. In March of the first year J.R. Raeburn obtained provisional Patent No. 521 for a cylindrical shale retort "having a circular, reciprocating or other motion" imparted to it. The vapour pipes were to be jointed so as to remain stationary while the retort moved. In December of the same year (1864) J.G. Winter patented "a revolving retort for distilling oils from coal, shale, etc.". This was the usual rotating tube heated externally by a coal fire, and /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

and the vapours were drawn off through the hollow shaft.

In 1865 J. Dougan patented a well designed horizontal cylindrical retort in which the charge was moved forward by a large screw mounted on a hollow shaft. Fig. 47 shows that proper provisions were made for ingress and egress of the charge. This retort was protected by Patent No. 1076 of 1865.

In December of the same year T.N. Bennie obtained provisional Patent No. 3101 for a retort consisting of a vapour tight box or "pan" fitted with charging and discharging doors. Through the cover passed a vertical shaft rotated slowly by steam power, and to which were fixed "claws or forks to turn over the shale while heat was applied to the pan".

In the same month J. Gibbon provisionally patented a revolving horizontal cylindrical iron retort for shale and cannel coal, the characteristic feature of which was the provision of a ridge running spirally round the inside of the tube to assist the forward movement of the charge (Provisional Patent No. 3285 of 1865).

In 1866 James Young evidently gave some thought to mechanically operated retorts, for his name appeared three times in the patent literature of that year on the subject of this type of retort.

His Patent No. 478 covered a well designed inclined rotating retort heated externally by a coal fire. This retort was notable in that it revolved on external rollers instead of being supported by /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

by the more usual hollow shaft. The upper end of the retort was fitted with the conventional round charging hopper of that period, and at the lower end the spent shale discharged through a water seal (Fig. 48).

Young's Patents Nos. 625 and 992 of 1866 refer to the fixed cylindrical horizontal iron retort fitted with an internal screw, already described as having been in operation at Bathgate Works. It is illustrated in Fig. 44.

In Patents Nos. 756 of 1866 and 707 of 1867, J.F. Brinjes described horizontal tubular retorts, the first of which was fitted with internal rotating paddles, and the second of which itself revolved and was fitted with longitudinal ledges or ribs, the better to agitate the charge on its passage through the retort.

F.L. Danchell's retort (Pat. No. 2714 of 1870), although intended for the distillation of wood or peat, is of interest and is shown in Fig. 49. It was similar to William's retort of 1862, but was inclined and heated from below instead of from above. The charge was contained in light cylindrical iron drums which were allowed to roll down the heated and sloping floor of the retort, one being removed from the lower end as a cold freshly charged drum was admitted at the upper end.

T.R. Crampton's vertical continuous retort 1872 (Pat.No. 2262 of 1872) although intended for gas manufacture is of interest historically /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

historically. Pulverised coal was fed to the upper end of the retort by a screw and in falling through the highly heated but empty retort was carbonised. The coke dust in the lowest part of the retort was of sufficient depth to form a seal and was continuously stirred by a water cooled stirrer and removed mechanically from the retort by revolving arms and a conveyor.

In 1872 also R. & F. Porter of London described a vertical iron retort heated externally and fitted with an internal close fitting screw so sloped that the charge rested against the hot walls and the vapours escaped by the centre of the charge to a top offlet pipe. The retort (illustrated in Fig. 50) was intended for destructive distillation generally, and could be adapted for shale distillation by admission of "steam, heated air or gas". (Patent No. 1494).

In the year 1872 also there was patented a retort by J. Inray (Patent No. 325), which, though intended to treat coal dust, is nevertheless of interest in the present study. It consisted of a horizontal covered annular cast iron trough in which molten lead was kept circulating by a paddle wheel and heated from below. Coal was forced under the lead by a piston feed arrangement and the lead circulating paddle also removed the residue. It is shown in Fig. 51. A very similar arrangement was tried out at Pumpherston Works after 1900 for distilling shale, but without much success.

In 1873 J. Patison of Airdrie proposed and patented (No. 569)



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

an inclined screw operated retort which had unique features, shown in Fig. 52. The retort was of iron, slightly tapered to its lower end, and was intended for the production of oil from shale and cannel coal. The internal screw was hollow and cooled internally by water or steam. It was of increasing pitch in order to thin out the charge at the lower or hotter end of the retort. The main feature of interest, however, was that the oil-free residue was fed by the screw through openings in the retort into a furnace below and adjacent to the coal furnace, both of which heated the retort. The spent residue from the shale furnace was continuously withdrawn by means of a separate screw.

Still another screw operated retort was that designed by John Bell in 1874 (Patent No. 1824). Its distinguishing feature was that the axial rotating shaft carried portions of screw, alternating with flat blades or paddles, the first to feed forward the charge and the second to agitate it.

In 1875 D.A. Fyfe and W.H. Bowers devised a gas retort which is notable in that it was horizontal and of rectangular section, heated externally by two furnaces. The coal was moved along the bottom of the retort by an endless chain and hence into a water seal trough from which another chain conveyor removed the coke to hutches (Patent No. 101 of 1875) - (shown in Fig. 53).

A retort similar to this was actually in use at Broxburn about the /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

28.

the year 1885. It was fed by hand with powdered shale and consisted of a number of horizontal retorts superimposed on each other and traversed by a single endless chain which passed the charge downwards from the upper cooler retorts to the lower hotter ones. No further details of this retort are available.

In 1881 and 1883 two other mechanical retorts suitable for shale appeared in the patent literature. The first, by E.G. Brewer, was the subject of Patent No. 3379 of 1881, and the second by B.P. Walker and J.A.B. Bennet, was protected by Patent No. 335 of 1883.

Brewer's retort was a vertical iron cylinder of large diameter and heated externally (Fig. 54). A vertical central shaft rotating slowly carried with it a series of large diameter conical rings and flanges which kept the charge close up to the walls of the retort and moved it slowly downwards. It was thus a mechanised form of former vertical retorts with a central core.

Walker's and Bennet's retort was another edition of the screw operated horizontal iron cylinder. Air for the coal furnace underneath was heated by passing through the hollow screw shaft.

In 1886 and again in 1889 R. Haig patented large diameter vertical retorts (Nos. 11584 of 1886 and 6242 of 1889). These were externally heated vertical cylinders built up in sections, and of diameter even greater than height. A vertical shaft carried a series /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section e. Mechanical Retorts

series of rakes which alternated with fixed annular horizontal trays attached to the walls of the retort and almost touching the central shaft. Shale or coal fed into the top of the retort was stirred and raked from one tray to the other in its passage downwards. (The 1889 retort is shown in Fig. 55).

Finally another lead bath retort appeared in 1895 in respect of which C.H. McEwen obtained Patent No. 14617. This retort, which was intended to distil "kerosene shale", consisted of a closed horizontal iron vessel half full of molten lead, and through which the shale was dragged by an endless chain fitted with clats. The spent residue was removed from the lead bath by means of revolving horizontal vanes. This retort illustrated in Fig. 56.

##### Section f. Retorts in which the oil was distilled off by the sensible heat of combustion of part of the charge in the retort itself, i.e. internal combustion retorts

Quite a number of internal combustion retorts have been used in the shale industry in Scotland and at the present day a partial application of the principle has been successfully applied to conventional externally heated shale retorts.

Apart from the classic patent of Archibald 9th Earl of Dundonald of 1781, the first record of a proposal to inject air to promote internal heating in a retort was in the provisional patent No. 1957 granted to William Brown on 23rd August 1853. His patent was on "an improved mode of obtaining volatile products from bituminous /

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Section f. Retorts in which the oil was distilled off by the  
sensible heat of combustion of part of the charge in  
the retort itself, i.e. internal combustion retorts

bituminous coals and other bituminous substances".

This consisted in burning these substances "in a furnace so constructed that the upper portion of the charge" "is gradually acted on by the heat evolved from the lower portion of the charge so that the volatile matters" of "the upper portion of the charge are driven off before such portion has descended sufficiently low in the furnace to undergo combustion".

In March of the following year (1854) Brown obtained Patent No. 515 for a complete specification of his invention under exactly the same heading as his provisional patent. In this his retort is described as "an air tight furnace into which the bituminous coals, etc. are introduced and the volatile products thereof are disengaged and obtained therefrom" "by means of a fire inside the furnace". The furnace was provided with bars and a furnace door, and at the top of the furnace was a hopper through which the bituminous coals, etc. were "introduced into the furnace, and at the top of the furnace was also placed a still head for receiving the volatile products when disengaged".

Eleven years later, J. Watson and J. Player provisionally patented a similar arrangement (No. 3296 of 1865). A blast furnace type of retort was proposed for oil shale, the furnace to have a charging /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section f. Retorts in which the oil was distilled off by the sensible heat of combustion of part of the charge in the retort itself, i.e. internal combustion retorts

charging hopper and vapour pipe on top and facilities for withdrawal of residue and admission of air at the base.

In 1872 Jas. Young was granted Patent No. 618 in respect of an internal combustion retort or "kiln" consisting of a brick lined iron cylinder with a bottom door for withdrawal of residue. The retort was arranged for downward distillation, and the gases passing the condenser were drawn upwards through a tower filled with coke, and down which "heavy hydrocarbon oil" flowed. The retort is illustrated in Fig. 57.

This scrubber system of recovering naphtha from the gases was actually in use at Bathgate in 1868, and was followed by the compression and cooling system in 1874, when J.J. Coleman was granted Patent No. 3577 and set up plant at Bathgate Works a year or two later.

On July 12th 1873, E. Meldrum of Dechmont proposed (in Patent No. 2407) still another modification of the internal combustion retort for distilling shale. This was a firebrick lined cylindrical vessel with four bottom openings and a top shale charging opening. Into two of the bottom openings air was drawn and from the other two spent shale could be alternately pulled and pushed out by an iron rake sliding on rails in the bottom of the retort and operated when desired by steam power.



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section f. Retorts in which the oil was distilled off by the sensible heat of combustion of part of the charge in the retort itself i.e. internal combustion retorts

A feature of interest was that part of the incondensable distillation gases were re-introduced to the retort some way above the air inlets.

In the following month D.J. Kennelly also patented a large internal combustion retort for shale (No. 2813 of 1873). This was a domed top hollow brick cylinder of large dimensions with a false bottom and a vapour offlet pipe below (see Fig. 58). Distillation was downwards and air was admitted along with waste gases through openings above the level of the top of the charge. A steam jet in the offlet pipe controlled the air supply. The most curious feature of the retort was the provision of a closed cylindrical iron vessel in the centre of the charge. This was stated to be suitable as a retort for the dry distillation of peat or alternatively for use as a superheater.

Following the abandonment of the Young & Brash retort of 1867 (see page 52), W. Young in continuing his search for improvements in the conventional externally heated vertical iron retort investigated the principle of heating by internal as well as external combustion. The result was the Young, Scott & Stephens "Gas Lute" retort, of which a number were in use in Scotland about the years 1872/74. (Patent No. 2587 of 1872).

This retort did not entirely depend on internal combustion for the /

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the heating of the charge and was further complicated by a system of recirculation of permanent gases to prevent mixing of the products of combustion with distillation products, a system which ultimately proved to be unworkable except in skilled hands. The retort was essentially a long oval section tapered cast iron retort arranged for downward distillation (Fig. 59). The metal retort, however, was mounted on a short brickwork extension shaft, enlarged at its lower end to form a solid walled combustion chamber and fitted with fire bars and provision for admission of air.

Four of these iron retorts about 11 ft long and their supporting firebrick shafts about 4 ft long were mounted in an oven. The combustion of the carbon of the oil free shale inside the brick combustion chambers and brickwork shafts radiated heat to the oven containing the iron retorts above, while supplementary heat was supplied by external coal fires heating the oven. From the iron retorts the substantially oil free shale descended to the short brick supporting shafts and hence to the furnaces where air was admitted.

The products of distillation were withdrawn a little way up from the bottom of the metal retorts along with the products of combustion from the shale furnaces below. To prevent mixing of the combustion and distillation gases in the retorts, permanent gases were /

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were introduced at a point lower than the vapour offlets to seal or lute the distilling portion of the retorts. Steam was also passed into the retorts above the combustion chambers but at the base of the firebrick shafts.

Operation was semi-continuous in that spent residue was withdrawn from the firedoors at intervals and fresh shale charged to the top of the iron retorts immediately thereafter. The retort was difficult to operate with unskilled labour, but if properly managed, the low distillation temperature gave an oil of good quality.

In 1874 Chas. McBeath of Bellsquarry Oilwork patented a more conventional internal combustion retort which was a modification of his steeply tapered short cast iron externally heated retort of 1866 (See page 74 and Fig. 66). This retort was the subject of Patent No. 601 of 1874 and one form is illustrated in Fig. 60. The original short steeply tapered cast iron shell with external flue was retained or in a modification the retort was constructed of firebrick without flues. A distinctive feature was that the column of shale was supported on six slowly revolving toothed firebars driven by mechanical power. Air was admitted by controllable openings in a closed ash pit below the bars, and the rate of combustion and distillation was regulated by the suction on the /

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the retort vapour pipe.

In the case of the cast iron form of McBeath's retort illustrated in Fig. 60, some hot gases were permitted to enter the flue surrounding the retort itself by regulation of the chimney damper and the admission of air to the ash pit door. The bulk of the combustion gases however passed up through the shale column to carry out distillation by internal heating, while completely spent residue was removed from the ash pit door from time to time. The provision of the rotating firebars in the retort gives it the distinction of being probably the first shale retort in which the shale column was supported on, and the spent residue continuously withdrawn by mechanical extraction gear.

Internal combustion retorts went out of favour during the succeeding seven or eight years during which other forms of externally heated retorts were developed, particularly those utilising spent shale as fuel outside the retort itself. Around 1880 also, the importance of ammonia recovery was realised, and the necessity for higher temperature and injection of steam for its recovery was demonstrated by Beilby and Young.

A revival of interest in internal combustion retorts, however, occurred in 1882, when A.C. Thomson and A. Neilson patented a large brick retort of this type (No. 4769 of 1882), a number of them being in /



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in use at Walkinshaw Works in Renfrewshire charging a local coaly shale (Fig. 61). The Thomson and Neilson retort was of all brick construction with external flues heated by a separate coal fire common to four retorts. Each pair of rectangular sectioned retorts however opened at their lower ends into a cupola into which air and steam were blown through a tuyere. The hot gases from the combustion of the carbon in the oil denuded shale in the cupola passed upwards into the retorts to distil off the oil, aided by heat from the separately heated external flues.

By 1883 the Young & Beilby or Pentland retort had established itself as the most satisfactory instrument for maximum oil and ammonia production, but other inventors still persisted with designs which they claimed could give similar results without the relatively complex structure of the externally heated composite retort.

Notable among these, were the Couper Rae retort of 1883, and the Stanrigg retort of 1889, the former partly and the latter wholly depending on the internal combustion principle for heating the charge.

The Couper-Rae retort was the subject of Patent No. 5724 of 1883, and a modification made by P. Dow of Lanark in the following year, was covered by Patent No. 12,286 of 1884.

Both retorts were essentially of vertical cast iron construction built in ovens of four and heated externally to a low temperature by  
a /

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a coal fire, common to each set of 4 retorts. The vapour offlets were in the conventional position at the top of the retorts. Each retort, however, was mounted on a solid walled firebrick extension of relatively large volume, and which formed a combustion chamber into which steam and air were blown. The hot combustion gases and steam passed upwards through the iron retorts and carried with them the distillation products, ammonia etc., to the external condensers. The retorts were not fitted with charging hoppers and in operation, the withdrawal of residue by shovel was immediately followed by addition of a corresponding quantity of raw shale at the top of the retorts. In the Dow retort the metal and firebrick portions were lengthened, and instead of the air and steam being admitted at the lowest portion as in the Couper-Rae, these were admitted at several points vertically in the brick section in order better to control the internal temperature. The two retorts are illustrated in Figs. 62 and 63. Two benches of Couper-Rae retorts were built at Seafeld Works, West Lothian, but after working for a time they were abandoned.

In 1885 H. Aitken of Falkirk proposed a large brick built blast furnace type of retort unheated externally. Air and steam were to be introduced at the bottom to promote combustion, recycle gas a little further up and steam at a still higher point, these being for the purpose of controlling the temperature in the upper or distillation /

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distillation zones. Fig. 64 shows this retort, the air and steam inlets being at B, C, and D, recycle gas inlets at E, and upper steam inlets at F. The retort was the subject of Patent No. 6048 of 1885.

In 1889 Black & Neilson devised a retort similar to Aitken's and fifty of them were built at Stanrigg Oil Works, New Monkland, Airdrie (1865 to 1900). These retorts handled a locally mined coaly shale and were in operation until the year 1900. They were the subject of Patent No. 9783 of 1889. Of oval section, built of fire-brick clad in iron sheeting they were externally unheated. Raw shale was charged from a large cone shaped hopper on each retort below which were two vapour offlets, while the curved base of the retorts facilitated the withdrawal of residue through two cast iron side doors. These Stanrigg retorts were remarkable for their large size. They were 50 feet high and contained 50 tons of shale and as the throughput was from 10 to 12 tons per day, the charge remained in the retorts for 4 or 5 days. When insufficient heat was obtained from the combustion of the oil denuded shale alone, coke breeze was added to the charge. The crude oil was given a preliminary distillation on the site and for a number of years the crude paraffin scale was sold to the Pumpherston Company.

With the dismantling of the Stanrigg retorts, the interest in purely /



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purely internal combustion retorts for distilling shale in Scotland also disappeared. Mechanical modifications of the Pentland retort were being developed intensively, and for many years gave eminently satisfactory results. Beilby, however, experimented with air injection into Pentland retorts about 1884, and in 1889 W. Young built many retorts which depended for part of their heating on the injection of air into them along with the steam, without however achieving much success.

##### Section g. Retorts in which the oil denuded shale was used as fuel for heating the retorts, in an external furnace

The use of "spent" shale as a supplement to coal in the firing of retorts marked a great and important step in the technical development of the Scottish industry. It was also peculiarly a Scottish development intended for application to a particular industry and a specific raw material. The oil denuded residue from Scottish shales contained, after distillation in the conventional cast iron retorts, about 12/14% of carbon, and this suggested itself as a fuel to many operators.

The first retort intended to utilise this low grade fuel was one of ingenious if impractical design proposed by E. Meldrum of Dechmont in 1865, and patented in that year (No. 2793).

A battery of retorts was formed by two long parallel brick walls between which were fixed transverse iron diaphragms dividing the space /



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space into a number of narrow rectangular cells, which might be used either as retorts or furnace spaces. A false bottom in each cell supported the shale, and beneath this was an offlet pipe to a condenser. The cells were closed in at the top and bottom with fire-clay and metal, and charging hoppers were fitted to the top plates. Each alternate cell was a retort heated by the combustion of the oil free residue in the cells on either side. When the retorting cells became exhausted, the carbonaceous residue was ignited and air admitted to promote combustion, while the former fire cells were discharged, recharged and closed in to become retorting cells again.

It is not known if this ingenious arrangement was tried out, but the next retort to be described was actually in use for several years from 1866. This was the retort designed and erected by Charles McBeath, who in 1866 when manager of Bellsquarry Oil Work (1864 to 1871) brought out the retort usually called after him. This retort was of relatively large diameter to length, was sharply tapered and was heated externally by the combustion of spent shale and added coal dross. Reference to Fig. 66 will show that its operation must have been most difficult.

Each retort formed a complete unit, the column of shale being supported on a circular bed of firebars of larger diameter than the retort. Oil denuded shale was at intervals raked out from the base of the retort and spread over the annular ring of exposed bars where it /

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it burned on contact with air admitted at the firedoors. The products of combustion of the shale and added coal dross circulated round the retort and hence to atmosphere through a flue near the top of the retort. The burnt shale and ashes were raked through the firebars and also out at the firing doors.

In order to prevent the arrangement operating as an internal combustion retort, the suction in the retort main and in the chimney flue were so controlled that only distillation gases passed through the retort and combustion gas round the retort flue. The retort suction was obtained by the round-about means of recirculating the vapours through a jet in the vapour pipe by the aid of a fan.

The retort was generally unsatisfactory in operation and was in use at Bellsquarry for a short period only. In 1874 McBeath patented a modification of his retort, this time adapted for internal combustion of the carbonaceous shale residue (Page 68 Fig. 60)

In the late 'sixties and early 'seventies there appear to have been many attempts to utilise as fuel the hot oil-free residue from shale retorts. Fig. 67 is taken from an undated Bathgate Works drawing of about this period, and shows an inclined retort with means provided for diverting the spent retort charge to the furnace below. Although there is some doubt as to this retort having been in actual use, Young's Company did adapt existing forms of vertical cast iron retorts to burn spent shale as fuel by dropping the contents /

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contents of the retorts into furnaces built underneath.

In order to separate the retort from the furnace and to control the dropping of the residue use was made of a "wedge discharge". This was simply a horizontal sliding door or damper which closed up the bottom of the retort. On withdrawing the wedge, spent shale dropped into a chamber below, from which it was raked forward into the furnace heating the retort. There retorts were operated in pairs over a common furnace so that one was distilling when the other was ready for discharge into the furnace. Figs. 68 and 69 show details of such a pair of retorts, these particular units being in use at Bathgate Works about 1872.

About the same year there was in use at Addiewell a similar retort, 12 ft long and 12 ins. in diameter at the top, designed to burn refinery tar as well as spent shale. The tar was injected into a firebrick compartment above the furnace and heated externally by it. The hot gases from the tar chamber passed into the retort flues along with the gases from the shale furnace below. A section of this retort is shown in Fig. 70.

Although there were many imitators, the principle of the utilisation of the residual carbon of the spent shale was finally most successfully applied by N.M. Henderson in his 1873 retort which he protected by Patent No. 1327 of that year. Many hundreds of these /

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these retorts were built in Scotland and indeed, in the years immediately following 1874 it was unsurpassed by any other in economy of operation and quality of oil produced.

In the Henderson retort a change was made to intermittent operation, with downward distillation, and the passage through the charge of highly superheated steam. Fig. 71 illustrates the general arrangement of retorts and furnaces. By the adoption of downward distillation it was considered that the oil vapours on passing through the shale bed, would be partially purified, and a better crude oil result. In actual practice the Henderson retort did give a better crude oil than the "old verticals" which it replaced, and Table II illustrates this point. <sup>29.</sup> Probably the main reason for this was not so much connected with the position of the vapour draw-off pipe as with the lower and steadier temperature of the Henderson retort through the use of oil denuded shale as fuel and also because of the construction of the retort oven which prevented the local overheating so common in earlier designs. The superheated steam which was a characteristic of the Henderson retort would no doubt also be partly responsible for the excellent oil which it produced.

#### TABLE II /



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TABLE II.

Finished Product	Crude Oil from No.1 Shale		Crude Oil from No.2 Shale	
	Old	1873	Old	1873
	Vertical	Henderson	Vertical	Henderson
Naphtha	Nil	1.50%	5.00%	5.00%
Burning Oil	41.45%	44.36%	33.30%	36.83%
Intermediate Oils	4.59%	1.64%	6.00%	3.00%
Crude Scale (Paraffin)	11.64%	13.00%	9.26%	10.48%
Lubricating Oil	16.66%	17.12%	15.40%	17.26%
Total Products	74.34%	77.62%	68.96%	72.57%

The retorts "A" (Fig. 71) were of oval cross-section and were placed in an oven common to a group of four. There were usually 48 retorts in a bench. They were 15' long and in cross-section were 1' x 2'6", and contained 18 cwts of shale. Under each oven containing four retorts were two furnaces from which the products of combustion entered the upper part of the oven through the port "E" and escaped to atmosphere from the bottom of the oven by the iron chimneys "F".

The oven temperature was normally 900-1000<sup>o</sup> F. and the temperature of the vapours leaving the retort 600<sup>o</sup> F.

A cast iron coil at one side of the oven served to superheat steam for injection into the upper parts of the retorts. The temperature of the injected steam was about 630<sup>o</sup> F. Every four hours the /

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the contents of one retort of a set were dropped into the furnace and recharged. Thus the shale remained in the retorts for 16 hours and the daily throughput of each retort was about 24 cwts of shale.

There being only two furnaces to four retorts, these were emptied of the burnt shale and ashes every eight hours by lowering the firebars "O" and allowing the waste to drop into the hutch "N". The tool "K" called "the Monkey" was used to manipulate the retort door "L" while the door "M" over the furnace, which in its open position also acted as a guide for the shale fuel entering the furnace, was opened and shut by means of a long-handled hook. Scrubbed gas entered the furnaces by the tube "R". The shale fuel entering the furnaces had a carbon content of 10 to 12% when Broxburn shale was used. Small coal was used to supplement the spent shale fuel.

Steam injected into the top of the retorts was sufficient to give an ammonia liquor make of about 70 gallons per ton, but owing to the lower distillation temperature, the yield of Sulphate of Ammonia was slightly lower than with the old form of vertical retort. The oil yields on the other hand were very similar although it was claimed that the newer retort gave a better oil (See Table 2). The actual yields obtained with shale from the Broxburn seam were 31 gallons oil, 16/17 lbs Sulphate of Ammonia and 2000 cubic feet of /

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30.

of gas per ton.

The retorts only required from  $\frac{1}{4}$  to  $\frac{1}{2}$  cwt of coal per ton of shale, and labour costs were also reduced. Thus ten men were able to deal with 65 tons of shale per day, while the "old vertical" retorts required  $14\frac{1}{2}$  men for the same throughput. No hoppers were fitted on the retorts, but they were charged direct from hutches running on rails along the bench top, thus eliminating the use of the shovel. For the spent shale also hutches were used, and these were hauled direct to the spent shale tip by means of an endless chain. It was usual for the hutches on their way to the spent shale tip to be hauled through a depression filled with water where the glowing residue was quenched. This quenching pit was commonly known as the "dipping hole".

Men who have worked with the Henderson 1873 retort tell about the immense clinkers which were formed in the furnaces, some of them too large to be taken out without first being broken up.

The success of the Henderson retort led to its adoption in many works in Scotland such as Broxburn, Uphall, Addiewell, Hopetoun, Burntisland, Linlithgow, Philpstoun and Oakbank.

It is interesting to note that the first Henderson retorts were of round section and were built at Oakbank in 1874 where they continued in operation for 12 years. In the first retorts also incondensable /

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31.

incondensable gas was used instead of steam to sweep out the vapours.

When the Broxburn Oil Coy. commenced operations in 1878 Henderson retorts were adopted exclusively. By the year 1887 there were 784 of these retorts at Broxburn Works alone, arranged in 16 benches of various sizes. There were also 576 Henderson retorts at Addiewell Works.

It was claimed by the inventor that the oil from the Henderson retorts as used at Broxburn Works cost 2.31d per gallon, as compared with 3.27d for the Kirk type of old vertical retort and 4.28d for the horizontal retorts originally used there.

32.

Following the success of Henderson's retort of 1873 many similar designs appeared in the next few years, few of which reached the building stage and those which did sometimes involved their erectors in legal difficulties with Henderson.

The first was that granted Patent No. 3910 of 1873 to J. & R. Bell. Henderson's principle was adapted to the already well known but obsolete Bell "Edge" retort by so arranging the fire door below the retort that it could be used as a deflecting plate to guide into the furnace space, the hot spent residue as it was raked out from the end door of the retort above. The arrangement is shown in Fig. 72.

In 1875 Geo. Bennie patented a vertical cast iron retort adapted /



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adapted to burn "spent shale" as fuel and differing from Henderson's design only in detail (Pat. No. 3934 of 1875). Four vertical retorts were mounted in an oven, but distillation was upwards (as compared with downwards in Henderson's retort), and the "spent shale" was dropped directly into the furnace by lowering a conical bell at the base of each retort in turn. This conical bell was operated by a lever and a long rod passing through the axis of the retort and to this rod was attached a barred cage in order to present a thin layer of shale to the heated retort walls. Fig. 73 also shows that the completely burned residue was removed by dropping into a hutch running on rails in a tunnel below the setting.

Still another modification appeared in 1876 when W. Young, A. Neilson and A. Young obtained Patent No. 3894 in respect of a shale retort similar to the earlier flat box shaped retorts devised by W. Young about the years 1867/1872 but adapted this time for the utilisation of the residue as fuel.

Fig. 74 shows that a simple externally controlled sliding plate closed the base of the retort and on withdrawal, permitted the residue to drop into the furnace space.

Finally, W. Young elaborated this form of thin box-like retort in his Patent No. 1578 of 1880 (Fig. 75). This retort was of large size and could be built in benches containing many retorts. Each retort //

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retort was 4' x 9'6" in end elevation but only eleven inches wide from wall to wall. As in former retorts of this type, distillation was downwards.

Provision was made for using the "spent shale" as fuel in furnaces below, and for burning coal in small supplementary furnaces. Air for combustion was preheated in regenerators between the furnaces, where the steam for the retorts was also superheated. A number of these retorts were built at Straiton Works (three benches of 64 retorts each were planned), but before they were heated, Henderson instituted legal proceedings against Young, and the newly built retorts had to be dismantled.

Except in two later retorts, one by W. Young in 1881, and one by R. Bell in 1884 (to be described later), the use of spent shale as fuel in an external furnace was abandoned, as the work of Young and Beilby became known, and the Pentland retort was evolved therefrom.

##### Section h. Retorts in which the charge was heated in two temperature stages to give the maximum yield of oil and ammonia

It had for long been known that in the operation of the old vertical iron retorts, the longer the shale was allowed to remain in the retort the greater was the ammonia yield, and that ammonia recovery continued after oil ceased coming over. Hence it was usual to steam the retorts for several hours after the oil run stopped /

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of oil and ammonia

stopped, even although the daily throughput of shale was thereby reduced.

Table No. III. showing figures relating to a test on a  
Henderson vertical iron retort illustrates this point.

TABLE III.

Hour after Charging	Hourly Yield of Crude Oil in Gallons		Hourly yield of Ammonia (expressed as Sulphate) in lbs.	
	No. I Shale	No. 2 Shale	No. I Shale	No.2 Shale
1st	Nil	0.993	4.010	2.137
2nd	0.96	1.325	2.811	1.441
3rd	1.85	1.987	0.561	0.701
4th	2.69	3.200	0.463	0.420
5th	3.16	3.646	0.330	0.343
6th	3.50	3.706	0.464	0.449
7th	4.06	3.500	0.515	0.547
8th	2.81	2.750	0.739	0.633
9th	2.25	2.090	0.980	0.601
10th	2.03	1.250	0.932	0.525
11th	1.94	1.250	0.572	0.759
12th	1.22	0.500	0.586	0.712
13th	0.86	0.385	0.462	0.569
14th	Nil	Nil	0.364	0.528
15th	Nil	Nil	0.405	0.448
16th	Nil	Nil	0.387	0.416
17th	Nil	..	0.165	..
Total	27.33	26.582	14.746	11.229

The value as fertilisers of nitrogen bearing chemicals such as Sodium Nitrate and Ammonium Sulphate was accepted long before the establishment /

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

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establishment of the shale oil industry in Scotland, but it was in May 1865 that Robt. Bell first produced Ammonium Sulphate from shale distillation liquor at Broxburn.<sup>34.</sup>

With the increasing importance of the substance and the rise in its market value every effort was made to increase the quantity made in the shale distillation industry.

Considerable work had already been done by H. Grouven, T. Richters and J.P. Rickman on the recovery of ammonia from nitrogen bearing substances by heating in closed vessels and in the presence of steam.

In 1878 an inclined retort for the production of ammonia from coke, etc. appeared. This was the subject of Patent No. 3341 of 1878 by J.P. Rickman. His retort was an externally heated steeply inclined fireclay lined iron cylinder into which was blown a mixture of steam and air. No temperatures were given in the specification, but it was stated that the ammonia might be "collected as an acid solution as Sulphate of Ammonia, Chloride of Ammonia, or the like".

In 1880 also T. Richters obtained Patent No. 2885 in respect of the recovery of ammonia from "azotic substances" such as "coal, peat, brown coal, bones etc." by heating in the presence of steam.

In the decade ending with the year 1881 G.T. Beilby (Oakbank Works) /



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##### Section h. Retorts in which the charge was heated in two temperature stages to give the maximum yield of oil and ammonia

Works) and W. Young (Clippens Works) separately carried out research and experimental work on the application of this principle to oil shale. G.T. Beilby in particular investigated the distribution of nitrogen in the products of retorting and showed that with shale from the Broxburn seam at Oakbank, distilled in existing vertical iron retorts in presence of steam, the distribution of nitrogen in the products was as follows :-<sup>35.</sup>

<u>Nitrogen</u>	- As ammonia in the watery distillate	- 17.0%
	- As alkaloidal tars in the oil	- 20.4%
	- In the spent shale	- 62.6%

With a view to increasing the proportion recovered as ammonia the use of slaked lime was very fully and practically tested by Beilby but it was found that at the low temperature most suited for oil distillation, no gain in ammonia yield was brought about.

Beilby and Young then treated the oil denuded residue or "spent shale" to a separate steaming to increase ammonia recovery. This was tried out in 1873 at Magdalen Bridge Works at Straiton and later<sup>36.</sup> more fully on a bench of Young's iron retorts at Oakbank Works. It was found that by continuing the steaming operation on the "spent shale" in the retorts for several days the nitrogen in the residue was still further reduced.

The actual results with the Broxburn seam were :-

Nitrogen /

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<u>Nitrogen</u>	- As ammonia in the watery distillate	- 24.2%
	- As alkaloidal tars in the oil	- 20.4%
	- In the spent shale	- 55.3%

The next step was to try out how far the ammonia recovery could be accelerated by the use of a higher temperature for the supplementary operation, and for this purpose experimental retorts were built at Oakbank Works.

After some preliminary work with an iron retort heated more strongly in the lower and steeply tapered section, a single composite retort was built in 1880 consisting of a 12" cast iron tube 8 feet long surmounted by the usual hopper and bell and jointed at its lower end to a 13" Stourbridge fireclay tube 5' long. The lower end of this tube was in turn jointed to an iron extension into which steam was blown and which dipped into a water seal trough. The whole retort was built in a double oven heated by a coal fire, the gases being so conducted as to heat the fireclay retort to a bright red heat and the iron retort to a much lower temperature. A section of this retort is shown in Fig. 76. The throughput of the retort was only about 10 cwts of shale per day but the results as far as ammonia recovery was concerned, almost perfect, only 4.9% of the nitrogen remaining in the spent shale. Expressing the results obtained more fully, the nitrogen was distributed in the products /

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products as follows :-

<u>Nitrogen</u>	-	As ammonia in the watery distillate	-	74.3%
	-	As alkaloidal tar in the oil	-	20.4%
	-	In the spent shale	-	4.9%
	-	Loss	-	0.4%

In the patents of the year 1881 we find the names of G.T. Beilby, W. Young and H. Grouven associated with the subject of ammonia recovery from nitrogen bearing minerals. Grouven's Patent No. 5504 applied particularly to peat and turf, but those of G.T. Beilby and W. Young applied to oil shale, and each described a retort specifically designed to subject the shale to a preliminary low temperature oil distillation followed by a high temperature treatment in the presence of steam. Young was granted Patent No. 1587 on 12th April 1881, and Beilby, Patent No. 2169 on the 18th of the following month. Young's description implied a long semi-intermittent all-iron retort, but Beilby definitely specified that the lower and hotter portion of his retort should be in the form of a fireclay tube, the retort being capable of semi-continuous operation.

Young's ideas were embodied in a retort erected at Straiton Works in 1881 and illustrated in Fig. 77. It was made up of two cast iron sections, the upper gently heated and the lower much more highly heated. The residue from the lower retort was to be used as /

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as fuel in a furnace below. Such a retort was not a practical proposition and was only used in experimental work.

The experimental iron and firebrick tube retort which Beilby set up at Oakbank in 1880 proved so promising that a bench of 16 of them was erected there in July of 1881. Towards the end of the same year 288 more were built at Oakbank, a few at Addiewell and Uphall and many more of modified design were built at Straiton and elsewhere up to the year 1883. Fig. 78 shows in part longitudinal section, the first bench of sixteen retorts erected at Oakbank Works, and Fig. 79 shows the corresponding cross section of the bench.

The Beilby retorts were arranged in sets of eight, each set being supplied with raw shale from two large cast iron hoppers to the top of which the vapour pipes were connected. Between each two sets of eight retorts were two large coal fires, one on either side of the bench and from which hot gases passed right and left to heat the firebrick tubes in two horizontal passes or heatings, before rising into a steam superheating chamber situated directly above the furnaces and communicating with the chimney.

The lowest parts of the firebrick tubes were thus heated to a bright red heat and the parts in the second pass of the gases to a somewhat lower temperature. To raise the metal retort chambers to a dull red heat, a portion of the fire gases was allowed to pass through /



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through dampers from the hotter zones below. Superheated steam was blown into the cast iron water seal extensions below the firebrick retorts and the steam and oil vapours were removed by vapour pipes attached to the raw shale hoppers above.

In the later Beilby retorts, modifications of the original design were made to facilitate working. Fig. 80 shows the ultimate form, in which the retorts were grouped in sixes instead of eights and the Stourbridge firebrick tubes were steeply tapered to minimise sticking and dandering of the charge. Fig. 81 shows another variation of the Beilby retort in which distillation in the iron retort was downwards and the passage of the steam in the firebrick retort upwards. Nothing is known about its working or where it was in use, but I.I. Redwood in 1897 described and illustrated it only as "Beilby's retort", the forerunner of the Pentland retort of Beilby and Young. Although Beilby had been able, almost completely to exhaust the shale of Nitrogen in his experimental iron and firebrick tube retorts, it was found that in large scale operation actual returns were less satisfactory. The principal reason for this lay in the construction of the retorts which were difficult to operate at maximum efficiency on the works scale. The firebrick tubes were extremely fragile, and cracking and leakages were common. Also with the removal of the carbon of the spent shale /

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shale under the action of the steam, the mineral matter tended to fuse and "dander" together in masses and to the walls of the fireclay tubes. Attempts to dislodge the fused shale damaged the tubes. Instances occurred where these failed after only a few months working, so that by 1885 few Beilby retorts were still in operation and some of the companies which had adopted them had suffered severe financial loss thereby. The joints between the cast iron and firebrick sections of the retorts also gave much trouble with leakage of oil vapours. As an indication of Beilby's realisation of these difficulties, we note that on October 2nd 1881 he took out Patent No. 4284 for an arrangement of counterweighted levers to suspend the iron retorts and to take the weight off the fireclay tubes; alternatively an all-brick retort was proposed.

Neither Young's nor Beilby's retorts being completely satisfactory in operation, but the principle of their action being similar, the two experimentists together designed a more workable proposition in the Pentland or Young & Beilby retort of 1882, and protected by Patent No. 1377 of that year. The first bench was erected at Pentland Works at Straiton in 1883 and was so successful that the retort was soon almost universally adopted by the major oil companies in Scotland. Among the better known Works where it replaced the old verticals were; Addiewell, Uphall, Hopetoun, Pumpherston /

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Pumpherston, Oakbank, Holmes, Burntisland, Tabrax, Straiton, Deans, Dalmeny and Linlithgow. By the year 1890 there were erected at these works and operated under licence from the inventors a total of 3252 Pentland retorts. A later census, in 1897, several years after the first of the mechanically operated retorts had been introduced, gave the following figures:-

Henderson retorts (1873 design)	896
Pentland retorts	3,636
Various other kinds	396

The very earliest form of Pentland retort was fitted with a separate cast iron raw shale hopper to each retort as in Fig. 82. In this retort the cast iron section was 12 feet long and the fire-brick section only 10 feet. A characteristic of the standard design however was the large cast iron raw shale hopper which fed each group of four retorts. This was fitted with four charging lids and was heated on the bottom by the hot gases serving the metal retorts below. Because of its large capacity and peculiar shape it was locally known as a "Jumbo". Figs. 83, 84 and 85 show various aspects of the Pentland retort in use about 1883/84. Each group of 8 retorts formed a unit, and in the upper oven there were 8 iron shale retorts, the upper part of a firebrick coal retort surrounded by flues, and a cast iron tubular steam superheater. The firebrick portions of the shale retorts were built of /

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of plain firebricks and terminated at the lower ends in curved firebrick chutes or mouthpieces closed by 15" diameter cast iron doors, one door to each retort. In this respect it was very similar to Findlay & Jack's retort of 1875 (see page 42 ).

The sizes of the metal and firebrick sections varied somewhat, but about 1884, 8'4" and 12'0" for the respective sections were typical. The iron retort was oval in section and the lower retort rectangular, the whole tapering from 10" x 2'2" to 1'3" x 3'6". The curved chute was about 5'6" in vertical height and was unheated, whereas straight-through horizontal flues in four passes heated the straight portion of the firebrick retort. Steam was admitted through ports about midway up the curved chute and the retort vapours were drawn off through a single 7" diameter vapour pipe situated at the top of each "Jumbo" hopper, this position being intended to promote condensation and redistillation of the oil vapours. The vapour main ran along one side of the bench just below the hopper base level, while at the corresponding position at the other side was the main for the gas from the coal retorts. In the earlier retorts these mains were at the level of the oven floor and long vertical vapour pipes connected the retort necks to the mains.

As compared with practice at that date, the heating system was new, producer gas being used instead of open fires. The upper parts of /



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of the firebrick coal retorts were heated externally by separate flues in the same oven as the shale retorts.

The bottom parts of the coal retorts formed gas producers by the entry of air at the bottom and superheated steam further up, and while the coal distillation products and most of the water gas passed over into the coal gas main, the true producer gas from the lowest part of the coal retort passed out through ports, circulated round the coal retort in brickwork flues and hence into the ovens above. The chimney draught and the suction on the coal retorts were so adjusted as to ensure the proper division of the coal gases, i.e. the distillation gas and water gas to the coal gas main and the producer gas from the lowest part of the retort to the flues round the coal retort and the upper chamber. The secondary air for combustion entered from the atmosphere through a series of round ports and was heated in horizontal tubes placed in the flue gases passing downwards to the main flue underneath the bench.

Shale gas and the coal gas after stripping were burned in the shale retort flues. These flues, extended from one side of the bench to the other in 4 passes, the hot gases rising from each pass to the one above by vertical ports and hence into the upper chamber containing the metal retorts.

The purpose of this rather complicated arrangement for working the /

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the coal retorts was to recover the nitrogen of the coal as ammonia, by cooling and washing the coal gas before returning to the retort flues.

In the majority of the Pentland retorts built in Scotland however it was not considered worth while to recover the ammonia and the coal gas system was therefore simplified.

In the newer system the coal gas was not drawn off from the bench, but the coal retorts became gas producers proper and the combustible gases from them entered the shale retort flues directly through ports near the bottom. With this arrangement, the external coal retort gas main was unnecessary. Scrubbed shale gas was supplied to the retorts through separate pipes and in burning passed through the same flues as the producer gas. The hot gases leaving the retort brickwork flues passed into the metal retort ovens and hence to atmosphere. With the poorer shales as much as 2 cwts of coal were required per ton of shale but with some of the richer shales the aid of producer gas for distillation was not necessary.

The average Pentland retort had a throughput of 28/32 cwts per day, charged as 7 to 8 cwts of shale every six hours. The spent shale was withdrawn by means of shovels, this being done every six hours also. The shovel used had a long metal handle and the blade was small and sharp pointed.

The oven temperature was 800/900<sup>o</sup> F. while 1800/2000<sup>o</sup> F. was common /

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common in the lower flues, a higher temperature than would be permitted to-day.

The cost of running the Pentland retorts compared favourably with that of the widely adopted Henderson (1873) retort, while the yield of ammonia was multiplied by two or three.

The Pentland retorts, however, were not without their troubles, and the principal of these was dandering or fusing of the shale in the lower portion of the firebrick section. This was largely due to the shape of the curved chute at the bottom of the retort. The spent shale came away more easily from the front (nearest the door) and in consequence the back of the retort dandered readily. When the Pentland retorts were in use in Scotland, the 12 hour shift system was practised, and unless the strictest supervision was given to the discharging, the retorts were often not regularly and adequately moved, especially at the week-ends, when the men worked for 25 hours continuously. The fact that the manual labour about the retorts was usually provided by a contractor did not tend to promote careful working.

In an attempt to eliminate the back wall dandering trouble, J. Jones proposed and patented a modified Pentland retort in which the lower portions of the back walls of two adjacent retorts were removed (Patent No. 11134 of 1886). Thus the lower parts of the two /



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two retorts became a single large retort extending across the bench, and having two spent shale outlets. Two sets of retorts were altered to this design at Dalmeny Works, but in practice they were found to be inferior to the unaltered retorts in the same bench. The modification is illustrated in Fig. 86.

In the following year another modification of the Pentland retort, intended to reduce back wall dandering, was patented by Messrs W.M. Fraser and J. Snodgrass (Pat. No. 7867 of 1887). In this, the flue spaces between the back walls of adjacent retorts were bricked up, thereby preventing access of the heating gases to these parts where dandering was experienced. As the primary cause of the dandering, viz., slow movement of the shale down the back wall, was not removed, little improvement was noted.

In the Pentland retort as in its predecessor the Beilby retort, the second main difficulty in operation was leakage of gases from the retort at the point of junction of the metal with the brickwork sections. Beilby had already included in his second patent specification of 1881 (No. 4284 of October 2nd) an all-brick retort as an alternative to the composite construction. About 1884 therefore in an attempt to eliminate the trouble with leakage at the metal/firebrick joint several benches of modified Pentland rectangular sectioned retorts were built of brickwork only at Deans and /



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and Oakbank works. The flue system in the lower parts of these retorts was unaltered, and the upper brick sections which replaced the iron retorts were built in the conventional open chamber. Some of the later all-brick retorts were of circular cross-section tapering from 24" diameter at the top to 36" diameter at the bottom, and reaching the unprecedented total height of 50 ft. from the ground to the top rail level.

Although the initial results were satisfactory, the all brick construction was finally abandoned in favour of the composite construction owing to trouble with cracking and leakage of the retort wall, particularly in the cooler zones. Fig. 87 shows the all brick "Pentland" retort in cross section.

In all the "Pentland" retorts the vapour offlet pipes were connected to the tops of the raw shale hoppers, the intention being to promote the condensation of oil on the cool shale and its subsequent re-distillation as the charge descended. It was claimed that in this way the usual preliminary distillation of the crude oil in the refinery was rendered unnecessary. This was not realised in practice however and there is little doubt that the redistillation of the oil in the retort and hopper near their junction, was responsible for the accumulations of carbon which had to be removed from the Pentland retorts at regular intervals. The yield of oil was /

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was also probably reduced by the attempts to promote redistillation in the retort, as recent research has shown that maximum oil yield with minimum gas production is brought about by removing the vapours as soon as possible after release from the shale, this condition being obtained by connecting the vapour offlet to the retort itself and by passing through the retort the maximum possible quantity of steam or inert gas.

The "Pentland" retorts, owing to their relatively fragile construction and high temperature of operation, had not a very long life. With careful working 6 to 7 years life was obtained but as short a period as 3 years was quite usual if they were worked for maximum ammonia yield.

Despite their defects they were a very great advance on the vertical iron retorts which they replaced and no sooner was this realised than a number of new retorts appeared, all similar in principal but claiming some improvement on the prototype. Also several all-iron retorts of earlier date reappeared with provision for higher temperatures and admission of superheated steam. In several cases lawsuits followed and the new retorts were sometimes operated under licence from Young & Beilby.

Despite the failure of the all brick Pentland retort about 1884, two other all brick retorts appeared within a few years. Generally /

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Generally however modification took the form of increasing the length of the retort; for instance, there were erected at Seafield Works, by the Pumpherston Oil Co., two benches of 80 retorts, each having an increased length of 5 feet, the increase being partly in the metal and partly in the brickwork. The dandering trouble, however, was merely aggravated by this change.

Notable among the modified Pentland retorts were the Armour and Hermand retorts built at Breich and Hermand Works by the Hermand Oil Co. from 1885 to 1889, and the Tennent retorts built at Pumpherston Works about 1887. Of these three designs the second and third were of all-brick construction.

Armour's Breich retort, of which 120 were built at Breich Works near West Calder in 1885 under licence from Young and Beilby, was of oval and rectangular section in the metal and brick retorts respectively, the metal retort being unusually long as compared with the brick section. Four retorts were built in each set and 20 sets to a full bench. The total length of each retort was 25 feet, made up of 15 feet in the cast iron section and 10 feet in the firebrick section. The firebricks used in their construction were of unusual size, being 4" x 4" in section and grooved on all the joint faces. In addition special curved bricks were used to round off the inside corners.

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An important change from the Pentland retorts was the arrangement of the raw shale hoppers and vapour offlet pipes. Each retort was provided with a separate rectangular sectioned hopper and the vapour offtake pipes were cast into the upper part of the retorts themselves.

The heating flues were similar to those of the latest Pentland retort of that time, except that there were three horizontal passes instead of four. The flue gases after leaving the metal retort chambers passed down through flues in the outer wall of the retort bench and into a main flue under the bench. The heating was done by return shale gas supplemented by open coal fires charged from one side of the bench near ground level. Each fire served two sets or 8 retorts, i.e. there were 10 fires to a bench of 80 retorts.

The throughput of the Breich retorts was only about 30 cwts of shale per day so that the charge remained in the retorts for as long as 40 hours. The retorts at Breich were in operation until 1903 and gave results at least equal to those of the parent design (Fig.88)

In 1889, 160 all-firebrick Hermand retorts were built at Hermand Works, West Calder (Fig. 89). These were similar to the all-firebrick Pentland retorts, but had some novel features. The retorts were rectangular, built in sets of four, and each retort was surmounted by a separate oval section cast iron raw shale hopper 4 feet deep and 3'2" x 1'11" in section. A vapour pipe was fitted to /



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to the bottom of each hopper. The retort was 22 feet long in the shaft and tapered from 1'6" x 1'3" to 3'6" x 1'6". The curved discharge chute, of 5 feet vertical height, constituted a cooling chamber of 30 cubic feet capacity.

The flue arrangement was simple - one pipe supplying gas for each set of four retorts. The hot gases travelled spirally round each group of four retorts in six passes. At the end of the travel of 211 feet round the four retorts, the gases entered two flues running along the bench and heating the outer sides of the raw shale hoppers. At the end of the bench these flues united and the gases finally travelled through another long flue between the hoppers and so to the chimney.

The retorts were heated entirely by stripped shale gas, no coal being necessary with the shale handled at Hermand. As the temperature in the flues on the outside of the raw shale hoppers was over 900° F. explosions in the hoppers were not uncommon, and it was the usual practice to put down the vapour valves when charging the retorts with shale.

The throughput of the Hermand retorts was similar to that of the Breich retorts operated by the same Company - about 30 cwts of shale per day.

Although these long brick retorts gave very good results at first /

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first, they soon became leaky and gave inferior oil; thus the earlier experience with the all-brick Pentland retort was confirmed.

In the year 1886 another all-brick modification of the Pentland retort was patented by R.B. Tennent (No. 15,772 of 1886), and a half bench was erected at Pumpherston Works where Pentland retorts were then in operation.

The "Tennent" retorts had a simple form of cone-shaped hopper over each retort and each pair of retorts across the bench was operated as a unit (Fig. 90). The corresponding pair of hoppers were coupled together by a vapour pipe and the vapour exit mains were connected to the retorts by a pipe entering the top of each hopper. The retort itself was built of firebrick only, with the usual curved discharge chute but lined with cast iron for easy removal of the residue. An important feature distinguishing them from their prototype was that each single retort had its own flue system, and outside this were passages in which the combustion air was preheated. Fig. No. 90 shows that the air entered the structure at a point low down on the outer walls, passing upwards between the retort flues and the outer wall, and then down a central passage between the retorts before dividing to meet the heating gas entering at either side of the bench from longitudinal gas mains.

Between each pair of retorts also was a superheating chamber where /

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where steam for the retorts was superheated by the hot exit flue gases passing downwards to the flue under the bench.

The Tennent bench at Pumpherston was in operation for a few years only and proved to be inferior in every way to the Pentland retorts adjacent to it.

In 1884 R. Bell patented a simplified Pentland retort (No. 9285 of 1884) which had a very short firebrick section and arrangements for completing the combustion of the residual carbon of the spent shale by dropping it into a furnace and hence into hutches in a vault below the setting. There is no record of its ever having been in operation. It is illustrated in Fig. 91.

Two patents appeared for the modified working of Henderson's 1873 retort to give increased ammonia recovery. The less important was that due to D. Neilson and J. Snodgrass who proposed simply to inject a mixture of air and superheated steam to the top of the Henderson retorts after completion of the distillation for oil, but before dropping the spent charge into the furnace. This unsuitable method of working an iron retort was protected by Patent No. 4902 of 1885.

A more important modification of the Henderson retort was by the inventor himself and patented in 1883 (Patent No. 5873 of 1883). This patent actually covered two different retorts, only one of which /

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which was a direct modification of the 1873 design, the other being in shape though not in principle similar to the thin box-like retorts formerly used by W. Young and others. The direct modification of the 1873 Henderson retort is illustrated in Fig. 92 and the other in Fig. 93. Although these retorts were certainly not widely adopted, there is reason to believe after perusal of an old yield book from Addiewell Works that a set of the type shown in Fig. 92 was in use there about 1889/90 giving a considerably increased yield of ammonia as compared with the unmodified Henderson retorts in use at the same time. Figures abstracted from this book show that whereas the 1873 Henderson cast iron retorts at Addiewell were in 1890 yielding from 10 to 12 lbs of Sulphate of Ammonia, the "converted Hendersons" were giving from 22 to 26 lbs per ton, a figure similar to that obtained from the Pentland retorts at the same Works.

In the modified retort described in the patent specification and probably used at Addiewell, the spent shale furnace normally serving four retorts was divided into two sections by a longitudinal brick wall. Each furnace section could be made vapour tight and was fitted with a vapour offlet pipe and valve through which steam, combustible gas and ammonia vapour could be drawn off to a main independent of the usual main for carrying off oil vapours from the iron /



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iron retorts above. Provision was also made for blowing in highly superheated steam and air to the lowest part of the furnace space when desired. When retorts were discharged into one or other of the furnaces, additional ammonia was recovered by connecting the furnace space to the ammonia main and blowing in superheated steam and air, the other section meanwhile acting as a furnace proper to heat the iron retorts for oil recovery in the usual way.

The second retort described by Henderson in the specification of Patent No. 5873 of 1883 treated the shale first by external heating and the internal passage of hot gases and then by the injection of air and superheated steam in the opposite direction to increase the ammonia recovery. The retorts (Fig. 93) were of thin section and built of brickwork only. They were fitted with bottom doors for spent shale withdrawal and the injection of air and steam, while vapours were also drawn off from the bottom of the retorts. The important departure from conventional operation was that the retorts were connected together in pairs by a top pipe and two retorts thus operated as a unit. Gas burning in flues heated the retorts externally but much of the heating was internal. The freshly charged retort of a pair was heated internally by hot vapours from the other retort into which steam and air (superheated in chequer brickwork below) was injected at the bottom, gases and vapours /

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vapours being swept through both retorts and leaving by the bottom of the cooler member. The operation was thus intermittent, each retort of a pair becoming an oil and an ammonia retort alternately.

Ingenious as were many of the methods for treating the shale with steam in two temperature stages for maximum oil and ammonia recovery, none proved so satisfactory as the externally heated retorts of Young and Beilby in which the low and high temperature retorts were superimposed and in effect formed a long shaft in which temperatures were progressively higher as the retort was descended.

G.T. Beilby, however, did experiment with the injection of air into Pentland retorts about the year 1882 not however with a view to increasing their throughput capacity. He reported that "the principal advantage of such a use of air was that a certain amount of heat is thereby generated within the retort, and consequently less has to be supplied from the outside, and a lower working heat can therefore be maintained". "This use of air, if properly regulated, did not sacrifice much of the Nitrogen of the coke". "It was also found that the increased volume of hot gases thus produced, tended to carry on the distillation of the shale in the upper retort under conditions favourable to the production of solid hydrocarbons". "In January 1883 a set of retorts worked alternately /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section h. Retorts in which the charge was heated in two temperature stages to give the maximum yield of oil and ammonia

alternately with steam alone and with steam and air showed with the latter, a gain in oil yield of about 10% and of solid paraffins, 25% i.e. a shale which with steam alone gave 30 gallons per ton of an oil containing  $10\frac{1}{2}\%$  of solid paraffin, gave with steam and air, 33 gallons per ton of an oil containing  $12\frac{1}{2}\%$  of solid paraffin".

"The steam used in both cases was equivalent to a make of about 72 gallons of ammonia liquor per ton of shale. In other sets of retorts a similar gain of oil and solid paraffin was obtained by the use of steam alone, 120/150 gallons of ammonia liquor per ton being condensed".

After discussing the relative advantages of excess steam and of air and steam Beilby dismissed the subject thus :- "As every volume of oxygen in the air took with it 4 volumes of nitrogen, the quantity of air that could be economically employed was very small". "The volume of gas from a ton of shale had already been increased by the new system (i.e. the two stage retort) from 2,500 up to about 14,000 cu.ft.". "This increase had already rendered the condensing and scrubbing of the more volatile parts of the crude oil a matter of considerable difficulty so that a further addition to the volume of gas through the admission of atmospheric nitrogen increased these difficulties and was looked upon as not economical".

40. 41. 42.

##### Section i. Mechanically operated two stage retorts

The principle of two stage retorting of oil shale in the presence /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

presence of steam having been established, and the Pentland retort having by 1885 proved itself to be a working success on the large scale and in all respects superior to its contemporaries, there followed a period up to about 1897 when several mechanised forms of the Pentland retort appeared in Scotland.

The comparatively unsatisfactory hand withdrawal of the spent shale in the Pentland retorts was replaced by some regularly operating mechanical withdrawal device and in some cases the retorts were increased in size to deal with a larger throughput of shale.

Profiting from the experience gained with these first mechanised two stage shale retorts, operators brought out improved forms which in turn were abandoned and replaced by still newer forms, some of which are still in use at the present day. In studying these mechanically operated shale retorts it is more convenient to trace the development of each design separately throughout the years instead of dealing with them strictly in chronological order.

The first name to appear in the Patent literature in connection with mechanical two stage shale retorts was that of N.M. Henderson of Broxburn whose vertical spent shale fired iron retort of 1873, and its modifications, have already been described.

After carrying out some experimental work at Broxburn in the late 'eighties Henderson took out a patent in 1889 on "Improvements in the Distillation of Oil Shale" (Pat. No. 6726 of 1889). In the same /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

same year a bench of 40 retorts as specified in this patent was built at Broxburn Works where after some modification it remained in operation for a number of years, although no more were built. The installation consisted of 10 sets of four oval and rectangular section retorts, and was locally called the "Maybrick" bench. The retort was of composite iron and brick construction, the two sections being 11 ft and 14'4" long respectively (Fig. 94). The upper oval section cast iron portion was substantially the iron retort of Henderson's 1873 design superimposed on and offset from a rectangular firebrick shaft, so that externally the retort bench was wider at the top than at the bottom and so presented a top heavy appearance.

Through the sloping ribbed cast iron throat connecting the iron and firebrick retorts the substantially oil free shale was drawn and crushed by a toothed roller slowly revolving in it. The teeth of this roller passed between the internal ribs of the throat and the intention was to crush the shale so that it might be more easily acted on by the ascending steam in the firebrick portion of the retort. Spent shale was extracted from the base of the brick retort by a similar single toothed roller on which the column of shale was supported.

The ratchet levers of the upper toothed rollers hung down, while those of the lower or spent shale extraction rollers faced upwards. The two side bars for moving the ratchet levers were thus /

4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
FROM THE YEAR 1850 TO THE YEAR 1915

Section i. Mechanically operated two stage retorts

thus taken as near as possible to each other and were driven by gearing from the same steam engine at the end of the bench.

Each retort was fitted with a separate rectangular raw shale hopper. The vapour pipes were attached to the tops of the metal retorts and were extended downwards to join the horizontal vapour mains about 12 feet above ground level. Each retort had a separate cast iron spent shale hopper discharging to the side through a round door, an arrangement which involved a complicated system of points on the spent shale hutch rails which ran in between each pair of brick pillars supporting the bench.

The firebrick retort itself was built of special tongued and grooved firebricks about 4" thick and the heating flues, instead of passing from one side of the bench to the other as in the Pentland retort, were built so that each retort was individually heated. A new feature was that supplementary coal gas was obtained from a gas producer external to the retorts.

On starting up this bench of retorts at Broxburn, the upper extraction rollers were at once found to be unsatisfactory and unnecessary and were withdrawn, and the bench continued in operation for about ten years without them.

Within a year of the erection of the "Maybrick" bench at Broxburn Works the building of a new and improved bench was started, and in 1892/93 several benches were built at the Broxburn Oil Co.'s new /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section 1. Mechanically operated two stage retorts

new works at Roman Camp. These were the first really successful continuous mechanically operated shale retorts in Scotland, and the larger "Broxburn" retorts now in use differ from them only in detail (Fig. 95). These improved retorts of 1892/93 were longer than any of the old manually operated retorts, with the intention of giving them an increased throughput and a larger yield of sulphate of ammonia. It was also hoped that by increasing the relative length of the brickwork retort, lower temperatures would be possible and dandering trouble reduced. In practice, 900<sup>o</sup> F. and 1300<sup>o</sup> F. were adopted for maximum oven and firebrick flue temperatures respectively.

The retort was 27'6" long as compared with a maximum of 22 ft. for the Pentland, and of this, 11 ft. was in the metal section and 16'6" in the brickwork. The metal and brickwork retorts were oval and rectangular in cross-section respectively, tapering from 1'11" to 2'3" at the top of the metal to 1'8" x 3'6" at the bottom of the brickwork. The benches were 45 feet high. Spent shale extraction was by a single toothed roller mounted below each retort. Each retort was fitted with a separate cast iron spent shale hopper discharging to the side. Each firebrick retort was separately heated by its own system of horizontal flues and vertical ports, and the hot gases from each set of four retorts joined in three common flues to enter the oven containing four metal retorts.

The raw shale hoppers were made in the form of long rectangular boxes/



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

boxes extending from one side of the bench to the other and each serving two retorts. The boxes were divided by internal plates into two separate hoppers each so that in effect every retort had its own hopper. Between the top of the metal retort and the raw shale hopper there was a tapered cast iron distance piece into which the offlet pipe was cast, a satisfactory arrangement which Henderson retained unaltered in later retorts. The vapour mains were raised to the normal position at the offlet pipes. Firing was by return shale gas supplemented by gas from an external producer charged with small coal. A characteristic feature of these retorts was the row of flying buttresses along one side of the bench near the base. These were actually curved flues leading the waste gases from the downcoming oven flues of each set into a horizontal main flue at or under ground level, and by which they were connected to a brick chimney. The raw shale was charged during the day time only, as the top hoppers were large enough to hold 18 hours supply of shale. Broxburn Works was equipped with 500 and Roman Camp with 240 of these retorts.

Despite the improvements which it effected in the cost of producing oil and the increased yield of ammonia obtained from it, its throughput was only about 2 tons per day.

In 1901/02 a bench of still further improved retorts was built at Broxburn, and this was the first of the "Broxburn" retorts as we know them to-day. More benches were built at Broxburn later, and /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

and in 1904/05 the old plant at Roman Camp Works was also replaced by the newer retorts which are still working there. (Figs. 96 and 97).

The 1901 retort (Henderson's Patent No. 2664 of 1901) is similar to its predecessor except that by still further increasing length and by working to higher temperatures, a throughput of 4 tons per day has been made possible (oven and flue temperatures raised to 1100° F. and 1750° F., as compared with 900° F. and 1300° F. in the 1892 retort).

A bench of these retorts is 60 feet high from top to bottom rail level, and the retort itself is 34 feet long, made up of 14 feet of metal and 20 feet of brickwork. The taper is from 2'9½" x 1'2.3/8" at the metal top to 4'8" x 1'10" at the base of the brickwork.

An important change from previous practice is found in the spent shale extraction mechanism where two toothed rollers support the shale column, and by slowly turning outwards work the spent shale down into the bottom hoppers. These toothed rollers are built up by threading a number of four toothed cast iron members on to a 3" square steel shaft. The toothed rollers of the preceding retorts were built up in a similar way, but had much smaller teeth and the roller body was of relatively larger size. The general shape of the older member was a toothed drum, whereas the teeth themselves constitute the bulk of its successor. (Fig. 97).

The raw shale is charged into large steel hoppers covering four retorts, but divided by internal steel plates into four separate compartments /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

compartments, one serving each retort. Each of the compartments is fitted with a charging lid and contains 6 tons of shale, the intention being that the hoppers should be charged once a day only. In the most recent benches the hoppers are built in pairs instead of in fours, thus reverting to previous practice except as regards size. The spent shale hoppers are built of flanged cast iron plates, one hopper to each retort, and are closed at the bottom by cast iron bells operated by worm gearing. They discharge into hatches running on rails directly under the bench and not to the side as in previous retorts.

As originally designed, all the "Broxburn" retorts were built of special 4" x 4" section grooved bricks in the firebrick portion. The high cost and the large number of different shapes required, prompted the introduction of plain 9" x 4½" x 2½" firebricks, and these have proved quite successful over many years' use. At Broxburn Works an attempt was made to render the long iron retorts more manageable by casting them in three flanged pieces which were bolted together to form a complete retort. The practice was, however, soon discontinued.

##### The Philpstoun Retort

The next mechanically operated retort to be considered is that which was developed and used exclusively at the Philpstoun Works of Messrs Jas. Ross & Co.Ltd. (now demolished). This work was started /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Philpstoun Retort (Continued)

started in 1885 with Henderson's 1873 iron retorts, but in 1893 these were replaced by an improved form of Pentland retort which became known as the Philpstoun retort.

The first of these retorts followed the Pentland design very closely except that two coal retorts instead of one were built into the setting between each group of 8 shale retorts. The most important change however lay in the provision of an extraction mechanism, which, while replacing the curved manual withdrawal chute, still discharged the retorts in batches and not continuously.

Unlike the coal retorts of the Pentland benches, those at Philpstoun were of composite construction also, and in the upper oven the metal sections of the 8 shale retorts and two coal retorts were exposed to the hot gases rising from the brickwork flues. The fuel gas from the coal retorts was not drawn off from the bench, but passed out through two opposite sets of ports at the bottom and divided to go right and left into the flues of the shale retorts as in the latest Pentland retorts of that time.

The retort heating flues were similar to those of the Pentland retort but the waste gases from the metal retort ovens were conducted by short tubular iron flues into two brick flues running along the sides of the benches to a brick chimney.

Each retort was surmounted by a small raw shale hopper, and  
the /



4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
FROM THE YEAR 1850 TO THE YEAR 1915

Section 1. Mechanically operated two stage retorts

The Philpstoun Retort (Continued)

the vapours were drawn off from the tops of these to mains on either side of the retort bench.

In 1891 there appeared in the name of Orr & Sutherland, Patent No. 15,552 describing a form of release or discharge mechanism for shale retorts and this was used, later with modification, in all the retorts built at Philpstoun (Fig. 98). The cast iron spent shale hopper under each retort carried two  $2\frac{1}{2}$ " square transverse shafts to which were attached a number of cast iron arms or grippers. When closed, these grippers rested at an angle of  $45^{\circ}$  to the vertical, and supported the column of shale in the retort. By a suitable arrangement of levers, the grippers could be lowered or raised, thus filling the spent shale hopper or supporting the shale column as desired. The movement of the shale was thus in batches of one hopper each, this operation being carried out every six hours. This earliest form of Philpstoun retort and its extraction mechanism is shown in Figs. 99 and 100.

With the erection of new benches of retorts at Philpstoun Works, many improvements were made as regards size etc. but the spent shale extraction mechanism was retained unaltered, except that in some cases the movement of the gripper shafts was effected by mechanically operated side rods instead of by hand. In the latest benches erected, the retorts were built in sets of four, the coal retorts were /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section 1. Mechanically operated two stage retorts

##### The Philpstoun Retort (Continued)

were eliminated and supplementary heating gas was obtained from separate Dowson & Mason producers. The retorts were of increased length and were fitted with large steel raw shale hoppers. Between these hoppers and the 10 foot iron retorts were interposed cone shaped offlet pieces 2' long carrying the vapour pipes. The spent shale hoppers, while retaining the Orr & Sutherland release mechanism were also increased in size and in most respects the latest Philpstoun retorts became very similar to their contemporaries, shale throughput capacity not excepted.

At the time of closing down (1931) there were 352 Philpstoun retorts of various types in operation at Philpstoun Works. A cross section of one of the latest forms of this retort is shown in Fig.101.

##### The Pumpherston Retort

In 1894, Patent No. 8371 was granted to Messrs Bryson, Jones and Fraser in respect of the now well-known Pumpherston retort. In 1895 and 1897 other patents were granted (7113 of 1895 and 4249 of 1897) relating respectively to (1) the recovery of heat and production of gas by the injection of steam into the retort, and (2) the fitting of spent shale hoppers of such a design that two retorts could be discharged through a single opening.

After experimental work had been carried out on a retort at Pumpherston Works (where Pentland retorts were then in use) a bench of /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section 1. Mechanically operated two stage retorts

##### The Pumpherston Retort (Continued)

of 13 sets or 52 retorts was erected at Seafield Works in 1895. This bench of retorts was in operation until the works were demolished in 1930.

The Pumpherston retort is the only one of the present day shale retorts which is of round cross-section, and is built of special grooved firebricks. The retort is generally 30'1" long; but the most recently erected are 33'7" long. The taper is from 2'0" diameter at the top of the metal retort to 3'0" diameter at the bottom of the brickwork. Distillation vapours are drawn off from a neck cast in the top of the metal retort itself. The extraction mechanism consists of a round cast iron table about 3' diameter on which the column of shale rests. Through a hole in the centre of this table passes a vertical 2" diameter shaft, to the top end of which is pinned a curved horizontal arm just clear of the upper surface of the table. The curved arm is made to rotate slowly by means of a mechanically driven ratchet mechanism, and in so doing, a portion of the spent shale is swept over the edge of the table into the spent shale hopper below. The curved arm makes one complete revolution in approximately 90 minutes to give a throughput of 4 tons of raw shale per day. The cast iron spent shale hoppers are common to each group of two retorts across the bench and there are two spent shale hoppers and four retorts to each complete unit or set.

Each /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Pumpherston Retort (Continued)

Each retort has a separate steel raw shale hopper which is charged thrice daily, while spent shale hoppers are emptied every four hours by lowering the lever operated conical discharging bells. The heating gases travel spirally round each separate firebrick retort and then enter the common oven containing four metal retorts before escaping to atmosphere by the short iron chimneys which are mounted on top of the benches. The usual Pumpherston retort bench comprises 13 sets or 52 retorts, and for these 14 chimneys are provided. More recent installations have been built in benches of 16 sets.

In two installations the waste gases were brought down to underground flues by vertical ducts built into the retort bench walls and hence conducted to a single brick chimney.

The first Pumpherston retort patent specification of 1894 provided a separate spent shale hopper for each retort. These hoppers had side doors opening vertically and the doors faced each other over the spent shale hatch (Fig. 102). The first bench built at Seafield in 1895 had this feature, but all later benches had only two spent shale hoppers to each set of four retorts. At Seafield a second bench of 52 retorts was built in 1896/7, and a few years later Pumpherston retorts were erected at Tabrax. At Breich Works, where there were 120 Armour retorts (already described) 8 sets of Pumpherston /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Pumpherston Retort (Continued)

Pumpherston retorts were built in 1900/1. When the works shut down in 1903, these retorts were dismantled and were re-erected at Seafield Works in the following year.

In 1897 two benches of 52 retorts each were erected at Deans Works, and these retorts were notable in that steam cylinders were fitted to operate the spent shale hopper bells, an arrangement which was ultimately abandoned. Four more benches were erected at Deans Works in later years.

At Levensseat, two sets (8 retorts) were erected to distil the shale associated with the local limestone. The crude oil from these retorts was used solely for grease making.

The most recent installation of Pumpherston retorts was at Niddry Castle Works, which were started in 1902 with 2 - 16 set benches, or 128 retorts. Between August 1908 and February 1909 other two benches were commissioned there. All the retorts at Niddry Castle Works have metal retorts, 15 feet long, as compared with the more usual 11'6".

To summarise, Pumpherston retorts were in use at one time or another at Seafield, Deans, Oakbank, Levensseat, Breich, Pumpherston, Dalmeny, Niddry Castle and Tabrax. Of these only Deans and Niddry Castle Works are now in operation with a total of 568 retorts.

Two views of the "Pumpherston" retort are shown in Fig. 103.

The /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Young's Retort

Young's Paraffin Light & Mineral Oil Co.Ltd. was later in entering the field of continuous retort design, the first patent granted in the name of Wm. Young and John Fyfe being No. 13665 of 1897. The Young's retorts have followed very closely the original Pentland design except as regards size and the provision of mechanical extraction gear. The arrangement of 8 rectangular retorts to each set and the heating flues running from one side of the bench to the other have been retained, along with side draw-off for the spent shale.

The first Young's mechanical retort appeared in the form of an experimental set of four of them at Addiewell Works about 1897, and was the subject of Patent No. 13665 of that year. Following this, one bench each was built at Hopetoun and Uphall Works, where Pentland retorts were then in operation.

The Hopetoun bench started up in September 1898, and the Uphall bench one month later. Each bench consisted of 80 retorts in 10 sets of 8. The oval section metal retorts were only 8'6" long and the rectangular section firebrick portions, 16'6". These retorts (Fig. 104 ) had large top hoppers covering each group of four as in the Pentland design, although they were made of steel plate instead of cast iron. The vapour draw-off at the top of the hopper was replaced by a long 7" diameter closed end pipe with a slot along the /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Young's Retort (Continued)

the bottom, which passed into each hopper about two thirds of the way down. Thus there were only two 7" draw-off pipes for 8 retorts and one vapour main to each bench. Attached to lugs on each pipe were four heavy chains, one passing down to near the bottom of each retort. The vapour pipes were made to oscillate slowly by mechanism outside the bench on the opposite side from the vapour main. While the chains were carried down by the descending shale, their upward movement was intended to agitate the column of shale and so minimise dandering. In practice this arrangement was not successful, and the chains were removed and the retorts operated without them.

At the lower end of each retort shaft were two fixed cast iron downward sloping plates which guided the spent shale on to the extraction screw situated horizontally between the plates. These cast iron screws which were right and left handed towards either end and on which the shale columns rested, were slowly rotated by a ratchet arrangement and side bar along each side of the bench.

The base of the retort bench was built to form spent shale hoppers with side discharge doors, and into these hoppers the spent shale was discharged from the screws above.

It is interesting to note that although these retorts as erected were fitted with the right and left handed screw extraction mechanism /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Young's Retort (Continued)

mechanism, they were originally designed to operate with a quite different form of gear. In this the column of shale was to have been supported on widely spaced cast iron firebars between which oscillated a corresponding number of cast iron fingers or rakes attached to a transverse shaft above the firebars. The arrangement was abandoned when it was found to infringe some existing patents and the screw alternative was devised and adopted. Actually Fig.104 shows this abandoned form of extraction mechanism.

Between each set of 8 retorts there was a short built-in gas producer, the gas from which passed directly into the retort flues, without the aid of external pipes. These producers were intended for starting up only and were charged by hand from barrow loads of coal brought along the platform at the level of the extraction screws.

The throughput of the first Young's retorts was approximately 60 cwts of shale per day.

In the year 1898 one half of the experimental set of four Young's mechanical retorts at Addiewell Works was converted to a new experimental design, which reverted to manual withdrawal of the spent shale and introduced the principle of air injection as an aid to heating the charge.

Immediately following the experimental work with these modified retorts, W. Young took out Patent No. 15238 in 1899.

This /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Young's Retort (Continued)

This patent covered a shale retort which, although of conventional cast iron and firebrick construction with external flues, was manually operated and depended for part of its heating on air injected into it along with the steam.

The old idea of promoting condensation and redistillation of the newly formed oil by drawing off the vapours from the top of a tall raw shale hopper was re-introduced, with the additional complication that the hoppers were heated externally on the sides as well as on the bottoms.

The metal and firebrick sections of the new retorts were identical with those of the first Young's retort, but at the base of each retort was built a large combustion chamber forming a downward extension and into which air was injected along with the steam, and from which spent shale was manually withdrawn through an inclined chute every four hours.

To prevent the spent shale passing faster down at the front wall of the retort than at the back, as occurred in the Pentland retort, a cast iron apron plate was inserted in the upper part of the curved chute, near the front wall. The grouping of the retorts in sets of 8 and the arrangement of flues and built-in gas producers was unaltered.

In each retort outer wall there was inserted an inclined 3" tube fitted with a removable cap. This was intended to be used as  
a /



#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Young's Retort (Continued)

a rodding hole in the event of the retort "dandering" or hanging up. The vapour main at one side of the bench only was retained, but there were four vapour pipes to each set of 8 retorts instead of two. This was brought about by supplying each pair of retorts (across the bench) with a common hopper into the top of which the vapour pipe was inserted. Each of these hoppers had a vertical division plate not extending to the top, thus giving each retort a separate hopper, yet permitting the vapours from each to pass out to the collecting main at one side of the bench. This vapour main was sometimes of a vertical oval section.

Originally a separate steam operated air injector fitted to the lowest part of each retort supplied the necessary air for internal combustion, while the steam was passed in a few feet higher up. Later, the injection air was passed into the retort steam mains by means of one or more large Korting steam injectors, and the quantity of air being dealt with was measured by means of a portable anemometer at the inlet to the injector.

There appears to have been no attempt to utilise the internal combustion principle as a means of increasing throughput in these retorts as this was only about 60 cwts per day.

These retorts were by no means free from operational difficulties, and the air injection was stopped about 1905, although some /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section i. Mechanically operated two stage retorts

##### The Young's Retort (Continued)

some of them were worked as externally heated, manually operated units for many years after, notably at Uphall Works.

The two main troubles experienced were :-

(1) "Dandering" or fusion of the shale in the firebrick section of the retort, due no doubt to the poor control of the quantity of air injected and to the intermittent movement inherent to the manual withdrawal system.

(2) The difficulty of getting enough steam through the retorts. No more than 65 gallons of ammonia liquor per ton were obtainable, and it is interesting to note that one attempt to increase this took the form of passing the injection air through a tower down which hot spent liquor from the sulphate plant passed on its way to waste.

In the year of the patent (1899) one bench of 80 of these retorts was erected at the Addiewell, Uphall and Hopetoun Works of Young's Company and in 1900 a second bench was started at Addiewell Works, making 320 retorts in all. A cross section of a bench of the 1899 retorts is shown in Fig. 105.

The manually operated Young's retorts were followed by the design in use to-day and usually known as the Young & Fyfe. They are almost identical with the first Young's mechanical retort of 1897 except as regard size and arrangement of raw shale hoppers.

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section 1. Mechanically operated two stage retorts

##### The Young's Retort (Continued)

A throughput of 4 tons per day is obtained.

As in former designs each set consists of 8 retorts, but each retort has a separate steel raw shale hopper often with a cast iron base. The vapours are drawn off to mains at each side of the bench. The retort is 27' long, of which the oval metal portion accounts for 10' and the rectangular sectioned firebrick retort 17'. (See Table 5) The screw extraction gear and spent shale hopper arrangement are similar to the original design except that the screw is of somewhat larger diameter. The first benches had the usual small built-in gas producers for starting up, but the newer benches lack this feature.

As in the other forms of shale retorts in use to-day, the return shale gas is now supplemented by producer gas supplied by an external producer. A section of a bench of these retorts is shown in Fig. 106. The first bench of 64 retorts was built at Uphall in 1904. Two years later a bench of 80 retorts was put up at Hopetoun and between 1911 and 1913 Addiewell was equipped with three benches of 80 retorts each.

When the Young & Fyfe retorts were first erected at Uphall and Hopetoun, much trouble was experienced with the deposition of solid paraffin in the vapour pipes, which were cast into the top of the retorts /

#### 4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN FROM THE YEAR 1850 TO THE YEAR 1915

##### Section 1. Mechanically operated two stage retorts

##### The Young's Retort (Continued)

retorts themselves. When the Addiewell benches were erected, a change was made; the vapour draw-off was attached to the lower part of the raw shale hoppers and the retorts were cast plain. When a second bench of 80 retorts was erected at Hopetoun in 1918, the Addiewell arrangement of vapour pipes was adopted. It is open to question whether the paraffin deposition was really due to the position of the vapour pipes or to the low chamber temperature of 900° F. then adopted in working the Young's retorts, but the adoption of the higher position certainly reduced the quantity of dust drawn over into the mains with the retort vapours.

Of a total of 464 Young & Fyfe retorts built between 1904 and 1918, 400 are still in operation.

##### The Oakbank Retort

As early as 1896 A.C. Thomson patented a simple form of extraction gear for application to rectangular sectioned shale retorts (Patent No. 9944 of 1896). This consisted of a rectangular cast iron table placed below the bottom edge of the retort shaft in such a position that the column of shale was supported by it without spillage. Slightly above the longitudinal axis of this table there oscillated a pear sectioned member attached to a horizontal shaft which alternately pushed the shale over either side of the table into the spent shale hopper below (Fig. 107). This gear was applied /



4. A DETAILED STUDY OF THE DEVELOPMENT OF SHALE RETORT DESIGN  
FROM THE YEAR 1850 TO THE YEAR 1915

Section i. Mechanically operated two stage retorts

The Oakbank Retort (Continued)

applied to a set of "Oakbank" retorts erected at Oakbank Works in 1915 and the subject of Patent No. 6784 of that year. Only one set of six retorts was built and this was dismantled with the closing down of Oakbank Works in 1930.

The heating was on the lines of the original "Pentland" arrangement of side to side flues and vertical ports. The side draw-off system was adopted for the spent shale, but the built in hoppers were of such large size that they were emptied twice daily only. The spent shale outlet doors were rectangular and hinged at the top.

Like its contemporaries, the throughput of the "Oakbank" retort was 4 tons of shale per day. A cross section of the bench is shown in Fig. 109.

## 5. DEVELOPMENT OF SHALE RETORTING IN SCOTLAND SINCE THE YEAR 1915

Following the introduction of the "Oakbank" retort in 1915 no new shale retort designs appeared in the Scottish Industry, nor were more than minor changes in operation made in the succeeding twenty years. Since the beginning of the century the composite iron and firebrick construction had become the standard form of shale retort most suited to the peculiarities of Lothians shale, the only important difference between the four principal designs being in the extraction mechanism for the residue.

On the Continent, however, several radically different forms of shale retorts were in use and very many were proposed and some tried out for the low temperature distillation of bituminous coal. Although these retorts most of them mechanical, were claimed to be original and were granted patent protection, their basic principles had been patented and some actually used in the Scottish Shale Industry many years previously, as described in Section 4 e. of this paper.

In recent years large scale developments in shale retorting have taken place overseas, principally in Esthonia and in Manchuria. In the Baltic country, internal combustion retorts and rotating tubular retorts are in use but the most interesting designs are the tunnel kilns of the Eesti Kivioli Co.Ltd. and Eestimaa Olikonsortsium Ltd.

In Manchuria large internal combustion retorts are used exclusively, each capable of handling as much as 50 tons of shale per /

5. DEVELOPMENT OF SHALE RETORTING IN SCOTLAND SINCE THE YEAR 1915  
per day.

Much experimental work has also been done in the United States of America with retorts of many different types, including a group of Pumpherstons design.

A study of all these retorts indicated that none of them was likely to be so efficient as the best of the mechanical iron and firebrick Scottish retorts for maximum recovery of oil and ammonia from Lothians shale. Indeed most of these Continental and American retorts were designed to recover oil from shales which contained little or no Nitrogen.

The principal defect of the Scottish shale retort is its relatively small throughput of 4 tons of shale per day. With a view to finding a method of increasing throughput and reducing fuel consumption without sacrificing yield of products, some large scale research work was carried out in Scotland in the late 1930's.

Attempts to increase throughput by raising the firebrick retort temperatures speedily ended in failure but the principle of partial internal combustion which was unsuccessfully tried out in the Young's retort of 1899, the Couper-Rae retort and others, was re-applied with considerable success. After preliminary trials with a single experimental "Pumpherstons" retort, a group of 24 "Broxburn" retorts was in 1936 fitted with flowmeters, pyrometers etc. and a long programme of experimental work carried out, in which the author took part. The ultimate result of this work was that it became possible /

5. DEVELOPMENT OF SHALE RETORTING IN SCOTLAND SINCE THE YEAR 1915

possible to increase the throughput of the "Broxburn" type of retort to about 12 tons per day without any loss of oil yield, and with a maximum loss of Ammonia equivalent to less than  $\frac{1}{4}$  of the Sulphate of Ammonia normally obtained. The air necessary to maintain the required internal temperature was injected into the retorts in admixture with the steam and amounted to from 4000 to 7000 cubic feet per ton of shale, depending on the rate of throughput. By careful control of conditions it was found that fusion of the shale ash could be avoided, the working of the retort facilitated and fuel economised. Table IV. shows very briefly the results of these experiments with the "Broxburn" retorts.

TABLE IV.

Shale Throughput Tons/Retort/Day	Shale A.		Shale B.	
	Oil Galls. per ton	Sulphate of Ammonia Lbs per ton	Oil Galls. per ton	Sulphate of Ammonia Lbs per ton
4	20.12	31.68	-	-
6	20.55	29.20	-	-
8	20.41	29.07	-	-
10	20.00	27.33	-	-
4	-	-	21.20	31.54
12	-	-	20.95	23.22

Similar results were later obtained with an experimental group of 20 "Pumphreston" retorts and then two complete works were converted to operate on the partial internal combustion principle. In 1941 a newly erected unit of 104 modified "Broxburn" retorts was put to work, handling up to 1250 tons of shale per day - equivalent /



# 5. DEVELOPMENT OF SHALE RETORTING IN SCOTLAND SINCE THE YEAR 1915

equivalent to 12 tons per retort per day. This "Westwood" retort as it has been named, is identical with its prototype as regards size of metal and firebrick sections but differs from it in the following main points :-

- (a) Raw shale is stored in large overhead bunkers, filled by a system of troughed conveyor belts.
- (b) Each retort is fitted with a small hopper charged directly from the overhead bunkers.
- (c) The vapour offlet pipes have been greatly enlarged and are offset from the centre of the retort.
- (d) The spent shale extraction mechanism is of the standard Woodall - Duckham single roller pattern.
- (e) The spent shale hoppers are fitted with Woodall - Duckham pattern water-sealed doors.
- (f) A water spray in each spent shale hopper cools the shale and generates steam which passes up into the retort.
- (g) Cooled spent shale is handled by a system of troughed belt conveyors.
- (h) Retort waste gases generate steam on passage through waste heat boilers.
- (i) The retort structure is supported entirely on steel stanchions instead of the more usual brickwork piers.

A cross section of these retorts is shown in Fig. 109, such features as the overhead shale bunkers and the waste heat boilers being plainly visible.

The results obtained with the "Westwood" retorts have been very satisfactory, the oil yield being fully maintained and the loss of ammonia amounting to no more than one sixth of the normal yield.

Whereas /

## 5. DEVELOPMENT OF SHALE RETORTING IN SCOTLAND SINCE THE YEAR 1915

Whereas shale retorts operated with steam injection require from  $\frac{1}{4}$  to  $\frac{1}{2}$  cwt of producer coal per ton of shale retorted, the new retorts when operated at 12 tons throughput per day require no producer gas, and indeed surplus shale gas is available as boiler fuel.

Also the steam generated by the spraying of the spent shale in the hoppers and by the provision of waste heat boilers constitutes a considerable proportion of the steam requirements of the plant.

These retorts therefore represent the most recent Scottish practice in distilling oil shale.

TABLE V.

Showing dimensions of the principal two-stage  
composite iron and firebrick retorts of the  
Scottish Shale Oil Industry.



TABLE V.

	Length of metal retort	Length of firebrick retort	Total length of retort
Pentland retort (Pumpherstons 1884)	8'4"	12'0"	20'4"
Henderson's Maybrick retort, 1889	11'0"	14'4"	25'4"
Henderson's improved retort 1890/91	11'0"	16'6"	27'6"
Henderson's "Broxburn" retort 1901 and later	14'0"	20'0"	34'0"
W. Young's 1st retort 1897	8'6"	16'6"	25'0"
W. Young's 2nd retort (manually operated) 1899	8'6"	16'6"	25'0"
The Young & Fyfe retort, 1904 and later	10'0"	17'0"	27'0"
The Philpstoun retort of 1893	10'0"	18'0"	28'0"
The Philpstoun retort circa, 1913	10'0"	22'0"	32'0"
The Pumpherston retort of 1895 and later	11'6" or 15'0"	20'0"	31'6" or 35'0"
The Oakbank retort of 1915	13'1 $\frac{1}{2}$ "	17'6"	30'7 $\frac{1}{2}$ "



TABLE V.

Size of metal retort at top	Size of metal retort at base	Size of firebrick retort at top	Size of firebrick retort at base
10" x 2'2"	12" x 2'8"	12" x 2'8"	1'3" x 3'6"
11" x 2'3"	1'2" x 2'9"	1'3" x 2'3"	1'6" x 3'0 $\frac{1}{4}$ "
1'1" x 2'3"	1'3" x 2'9"	1'3" x 2'9"	1'8" x 3'6"
1'2 $\frac{1}{2}$ " x 2'9 $\frac{1}{2}$ "	1'5" x 3'0"	1'5" x 3'0"	1'10" x 4'8"
1'0" x 2'0"	1'2 $\frac{3}{4}$ " x 2'5 $\frac{1}{2}$ "	1'2 $\frac{3}{4}$ " x 2'5 $\frac{1}{2}$ "	1'7" x 3'4"
1'0" x 2'0"	1'2 $\frac{3}{4}$ " x 2'5 $\frac{1}{2}$ "	1'2 $\frac{3}{4}$ " x 2'5 $\frac{1}{2}$ "	1'7" x 3'4"
1'1 $\frac{1}{2}$ " x 2'6 $\frac{1}{2}$ "	1'4 $\frac{1}{2}$ " x 3'0"	1'4 $\frac{1}{2}$ " x 3'0"	1'9" x 3'11 $\frac{1}{2}$ "
1'1" x 2'3"	1'3" x 2'6"	1'3" x 2'6"	1'4" x 3'0"
1'2" x 2'6"	1'6" x 2'10"	1'6" x 2'10"	1'9" x 3'6 $\frac{1}{2}$ "
2'0" dia.	2'4" dia.	2'4" dia.	3'0" dia.
1'1 $\frac{1}{2}$ " x 3'7"	1'4 $\frac{1}{2}$ " x 3'11 $\frac{1}{2}$ "	1'4 $\frac{1}{2}$ " x 3'11 $\frac{1}{2}$ "	1'8" x 4'6"

NOTES ON RETORT SIZES SHOWN IN TABLE V.

1. Length of metal retort shown is the actual length of the casting. In the case of the Pumpherston, Oakbank and the earlier Young's & Henderson retorts the offlet neck was cast on to the retort itself. In the later Henderson retorts and in the Philpstoun retorts, a separate cone shaped casting above the metal carried the offlet neck and was bolted to the raw shale hopper.

In the latest benches of Young's retorts the offlet neck is cast on to the lowest part of the raw shale hopper.

2. In the Henderson Maybrick retort of 1889, the metal section was not directly superimposed on the firebrick section. (See page 109).

3. The length of the firebrick portion of the retorts is given as the total length of brick shaft, but in some cases (Pumpherston retorts and some of the Philpstoun retorts) the lowest few feet were made with a decreasing taper to guide the spent shale in the extraction mechanism.

In the case of the Pentland retort the length of the curved discharge chute is not counted in the length of the firebrick retort.

4. The cross-sectional sizes of the firebrick retorts are the minimum and maximum sizes at top and bottom respectively.

5. All the firebrick sections were symmetrically tapered except in the Henderson retort of 1893 and some of the later forms of the Philpstoun retort, which were tapered to the outside only, i.e. the inner retort wall was vertical.

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7. REFERENCES

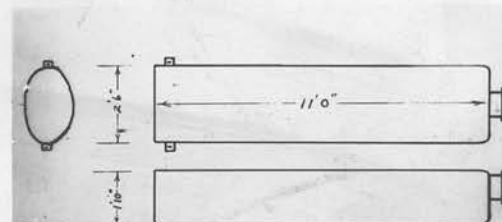
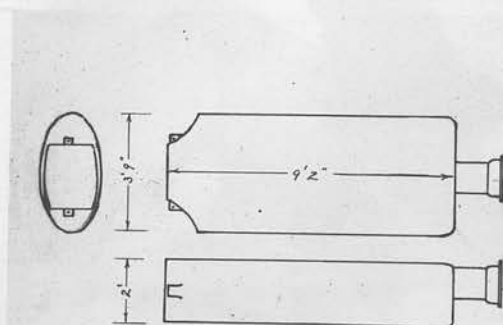
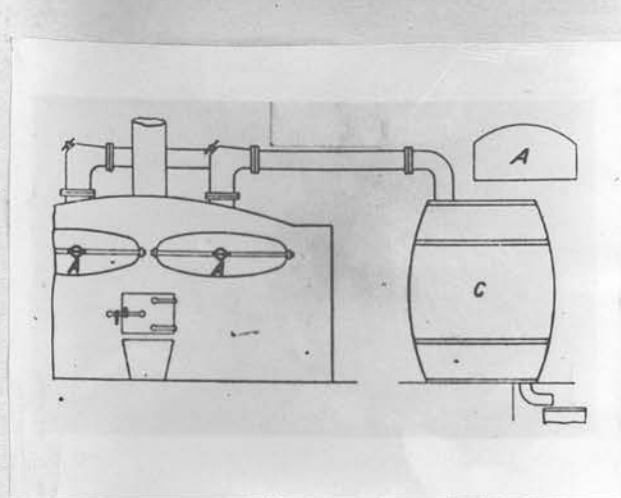
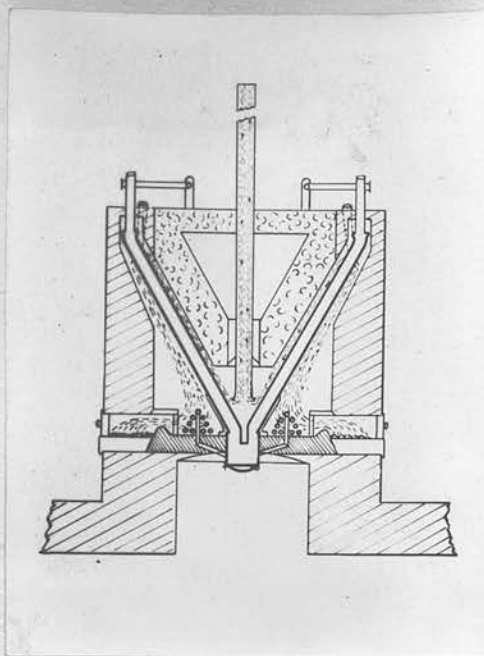
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8. ILLUSTRATIONS.

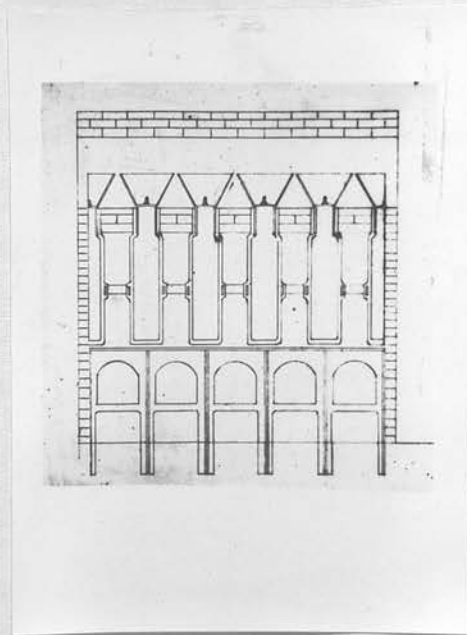
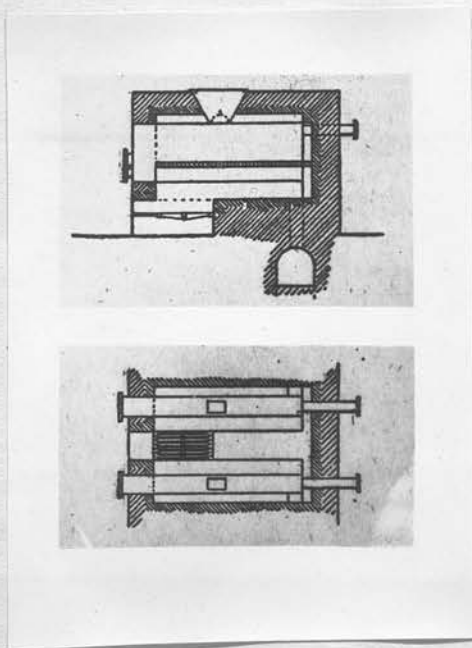
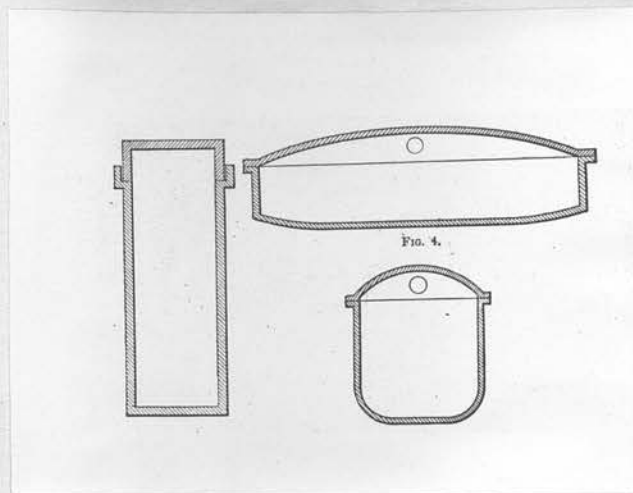
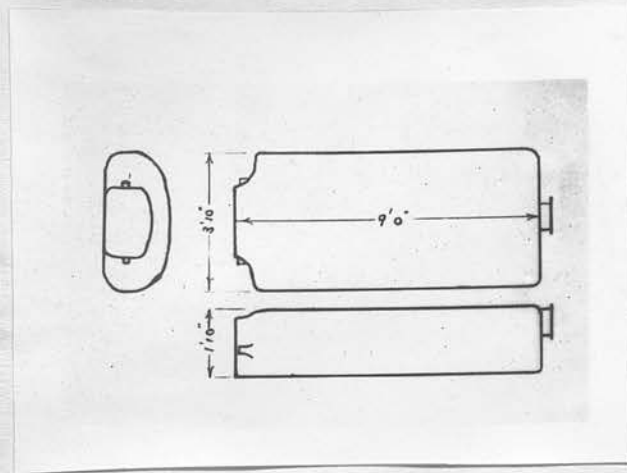


1. Michel du Buisson's conical C.I. shale retort. (Pat. No. 10726 of 1845).

2. R.A. Brooman's horizontal retort and condenser. (Pat. No. 516 of 1856).

3. Horizontal C.I. retort used at Bathgate Works up to 1865.

4. Horizontal C.I. retort used at Bathgate Works up to 1865.



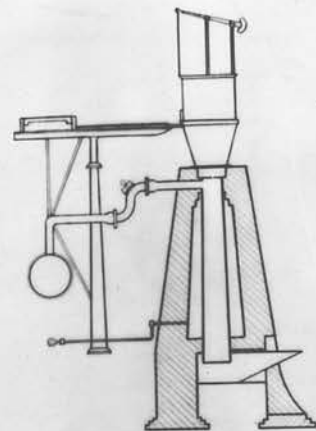
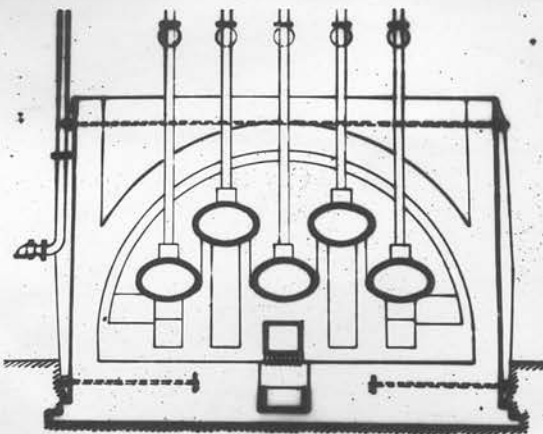
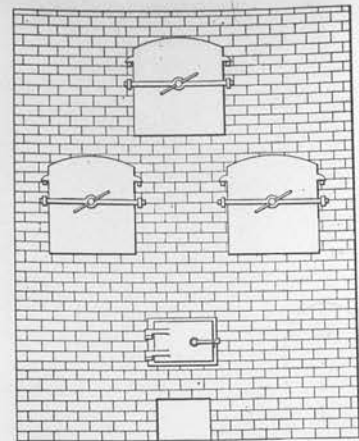
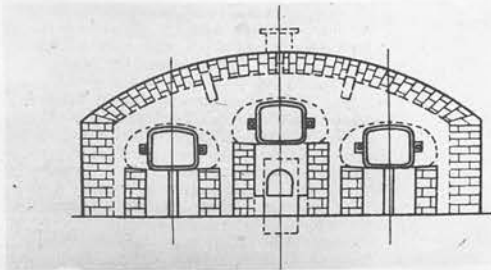
5. Horizontal C.I. retort used at Bathgate Works up to 1865.

6. 7. 8. Cross section of three less common forms of horizontal C.I. retorts (circa 1865).

9. Setting of two "Bell" horizontal "Edge" retorts.

10. Cross section of a "bench" of "Bell" retorts.



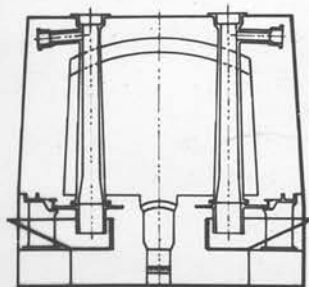
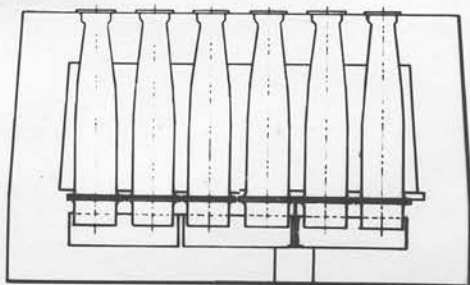
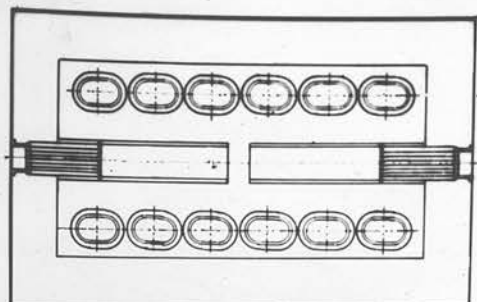
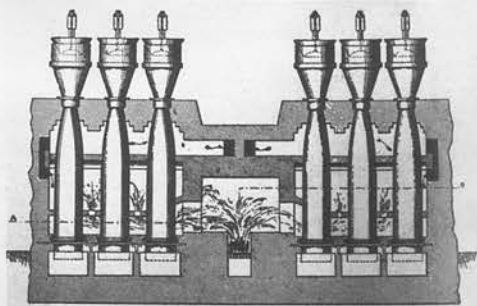


11. Cross section of setting of three - 6 foot horizontal retorts (dated 1865).

13. Sectional elevation of a setting of 5 oval horizontal retorts 9'1½" long, 18" high, 24" wide. (Bathgate Works, dated 1867).

12. Front elevation of another form of 3 retort setting.

14. Cross section of the "Kirk" vertical retort (about 1860 et seq.).

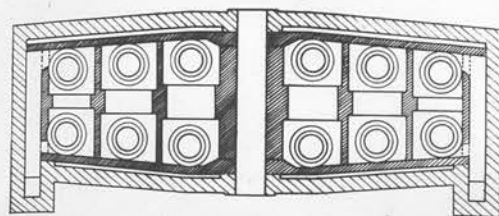
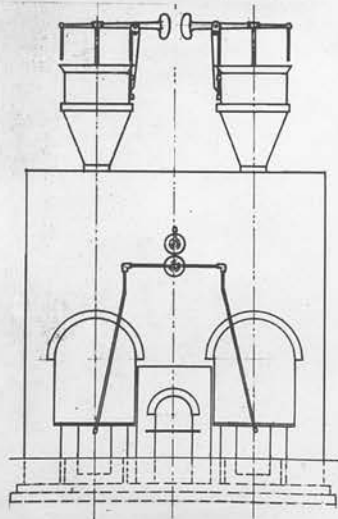
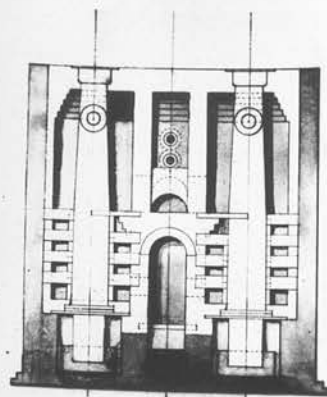
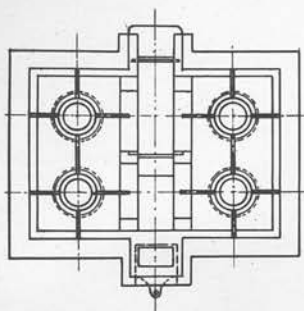


15. Longitudinal section of a setting of six "Kirk" retorts.

16. Plan of setting of 12 oval sectioned modified "Kirk" retorts, heated by two fires. (Addiewell 1877).

17. Longitudinal section of same showing two retorts to each water seal pan.

18. Transverse section of same, showing water seal pans and one of the two furnaces.

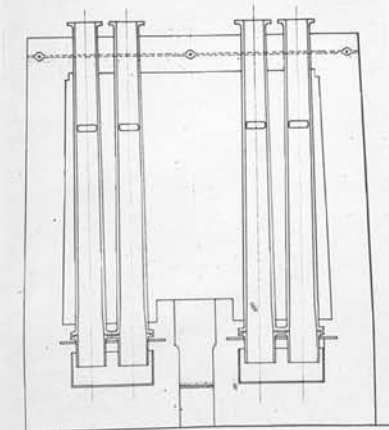
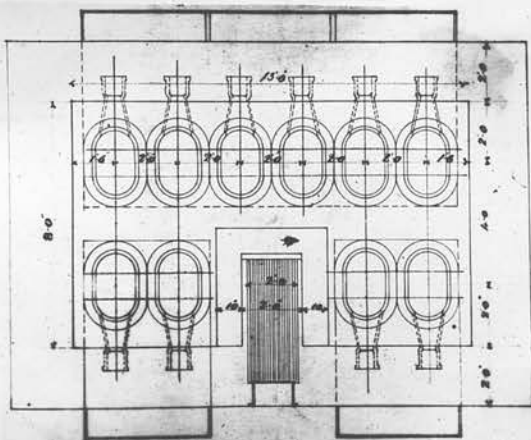
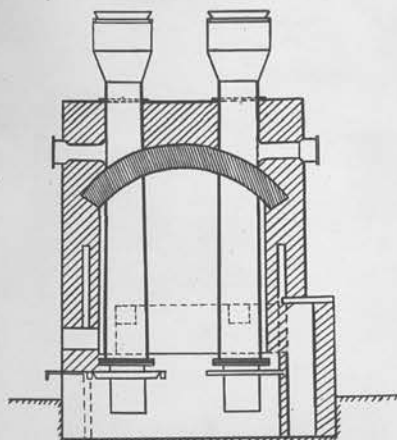
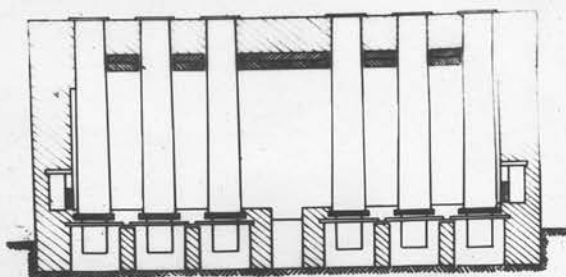


19. Plan of setting of four round section tapered retorts with water sealed discharge. (Bathgate 1862).

20. Transverse section of same.

21. Elevation of same showing shale hoppers.

22. Plan of setting of twelve round section tapered retorts heated by a single fire, arranged for water sealed discharge. (Bathgate Works).



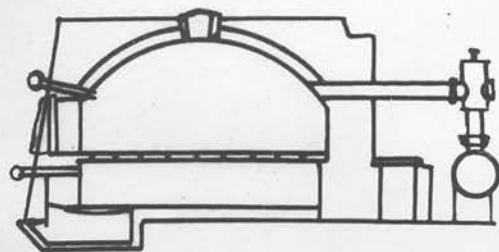
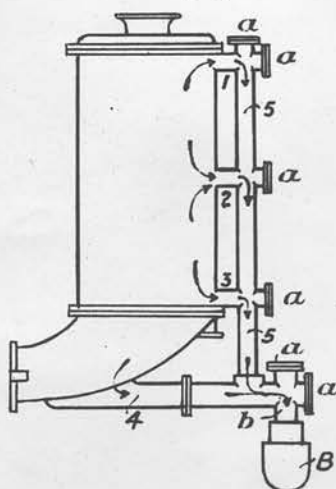
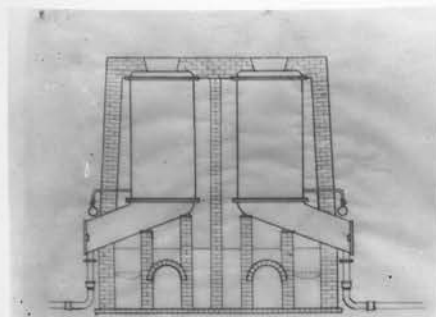
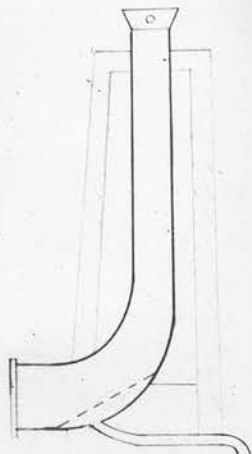
23. Longitudinal section of same.

24. Transverse section of same.

25. Plan of setting of ten oval section tapered retorts 15 feet long heated by a single fire and arranged for water sealed discharge. (Addiewell 1877).

26. Longitudinal section of same showing each pair of retorts sealed in a single pan.



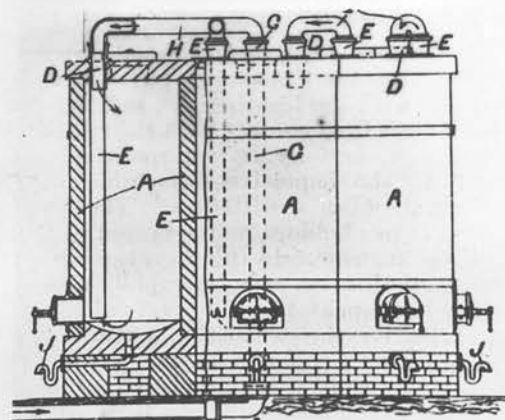
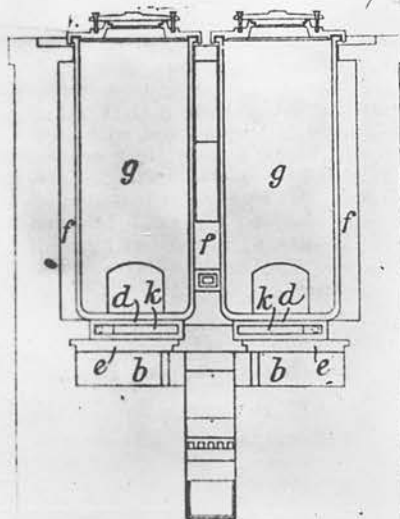
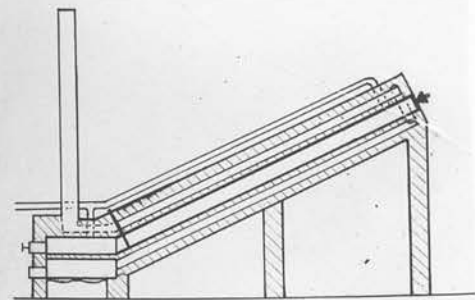
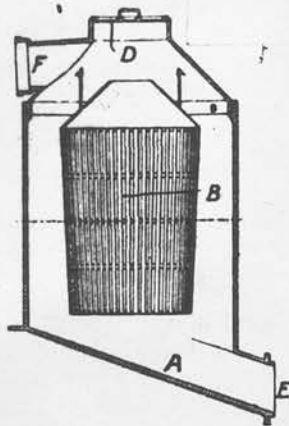


31. Sketch of the "Mollocher" retort. (Oakbank 1872).

32. Thin section vertical iron retorts for downward distillation. Retorts 1' x 5' x 10' (Midlothian Oil Co. 1872).

33. Thin section retort with curved chute outlet for residue and multiple offlets for vapours. (Pat.No. 930 of 1875). (Findlay & Jack).

34. Jas. Young's all brick beehive retort. (Patent No. 1481 of 1868).

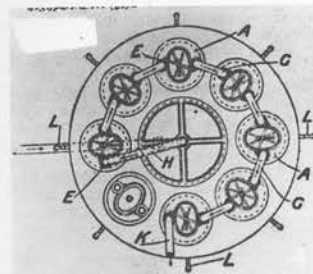
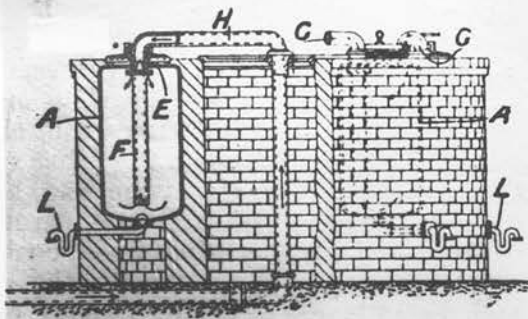
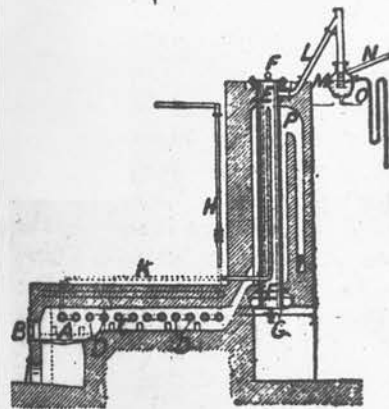
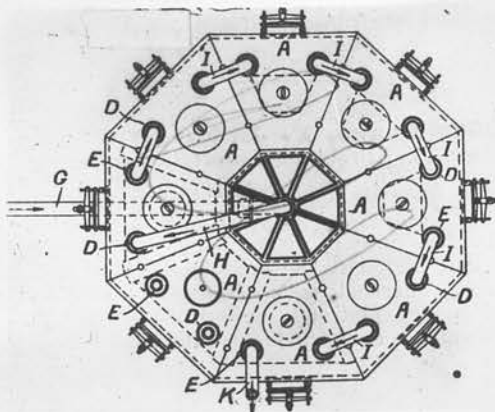


35. Walton's iron retort with central cage. (Pat. No. 1361 of 1865).

37. Howarth's superheated steam retort. (Pat. No. 1553 of 1865).

36. Griffith's inclined iron retort. (Pat. No. 2080 of 1863).

38. Jas. Young's continuous superheated steam retort, Sectional elevation. (Pat. No. 486 of 1861).

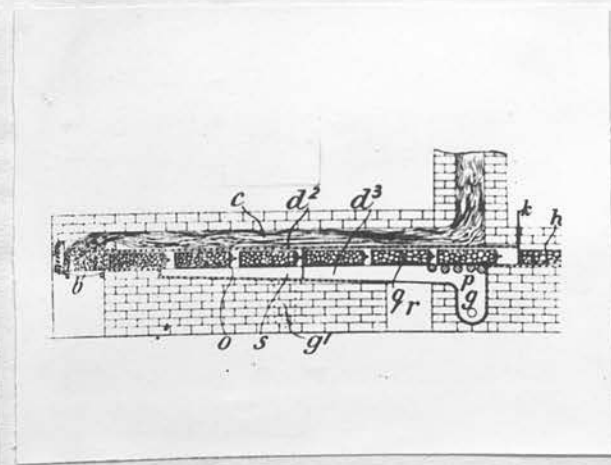
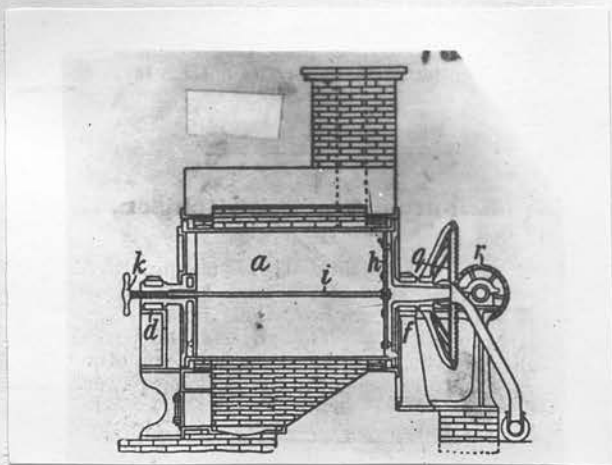
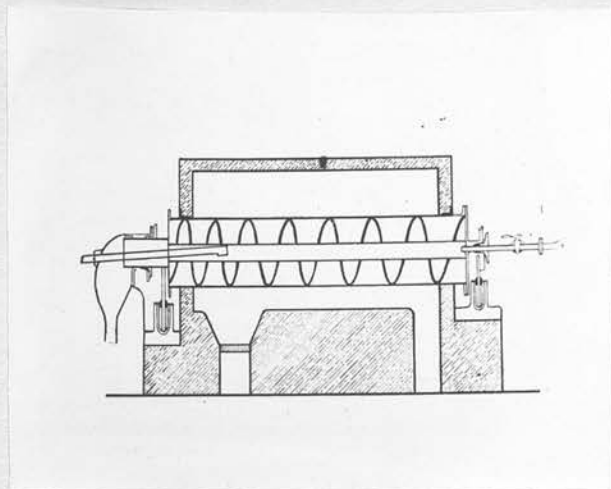
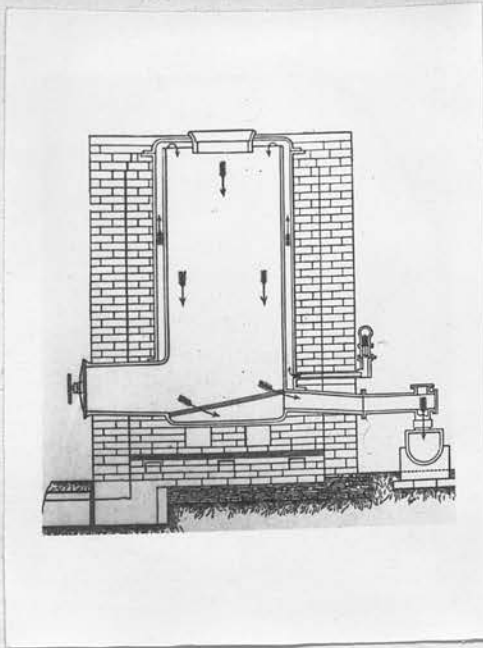


39. Plan showing the distilling chambers of Young's superheated steam retort. (Pat. No. 486 of 1861).

40. B.T.B. Mill's superheated steam vertical iron retort. (Pat. No. 69995 of 1884).

41. Jas. Young's continuous retort internally heated by hot gases. (Pat. No. 1349 of 1864).

42. Plan of Young's continuous retort of 1864. (Pat. No. 1349 of 1864).



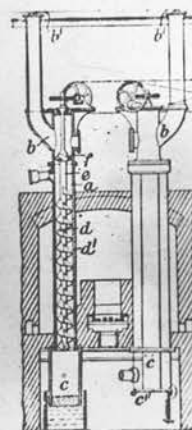
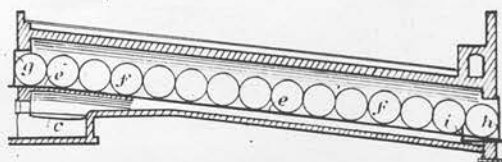
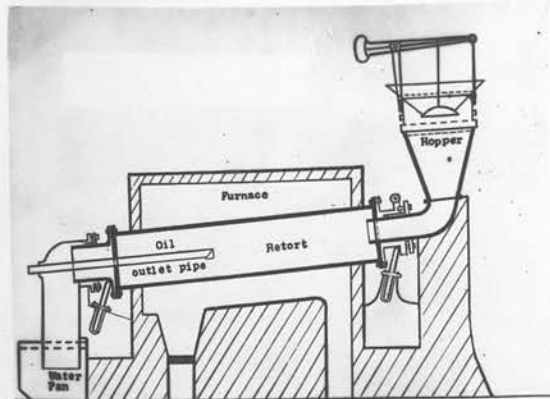
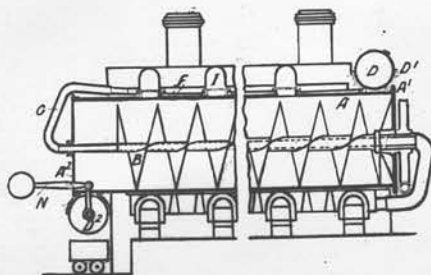
43. The Young & Brash internally heated retort. (Pat. No. 650 of 1867).

44. Jas. Young's screw operated externally heated iron retort. (Pat. No. 992 of 1866).

45. Bakewell's horizontal rotary retort. (Pat. No. 1698 of 1859).

46. William's continuous retort using iron containers for the charge. (Pat. No. 1940 of 1862).



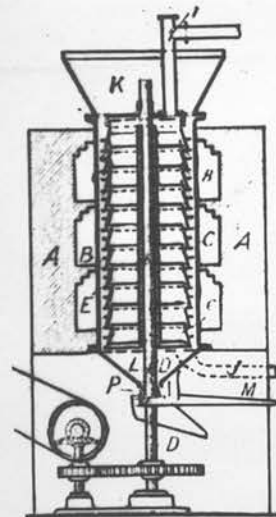
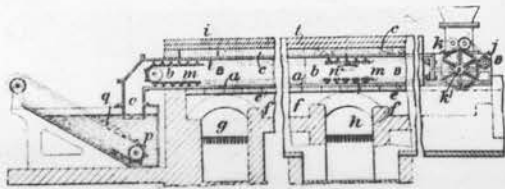
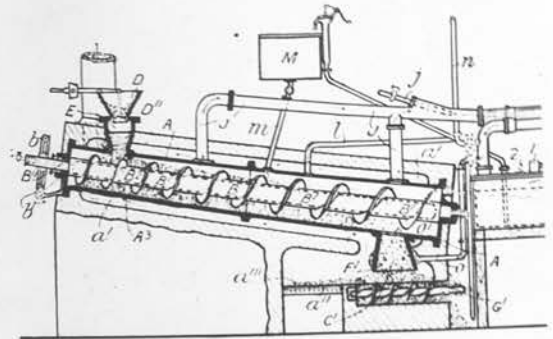
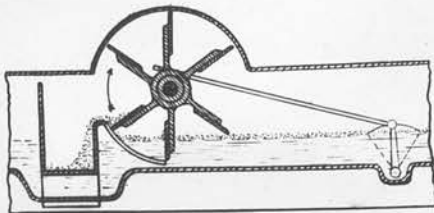


47. Dugan's screw operated horizontal iron retort. (Pat. No. 1076 of 1865).

49. Danchell's continuous retort using drum containers for the charge. (Pat. No. 2714 of 1870).

48. Jas. Young's inclined rotary externally heated iron retort. (Pat. No. 478 of 1866).

50. R. & F. Porter's screw operated vertical iron retort. (Pat. No. 1494 of 1872).

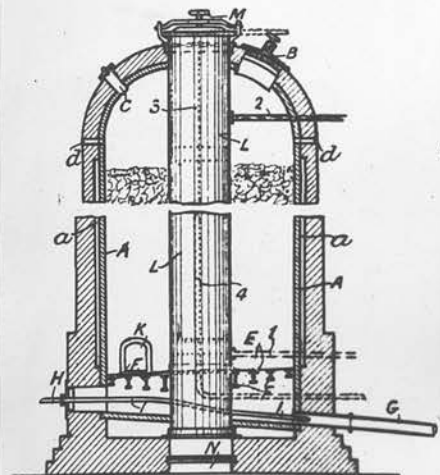
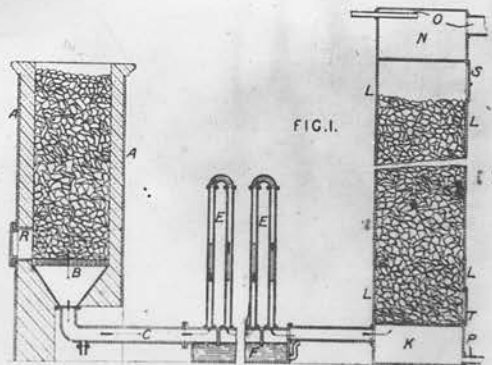
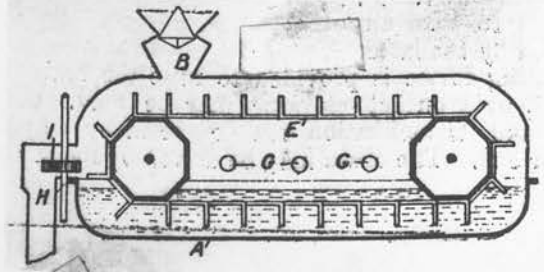
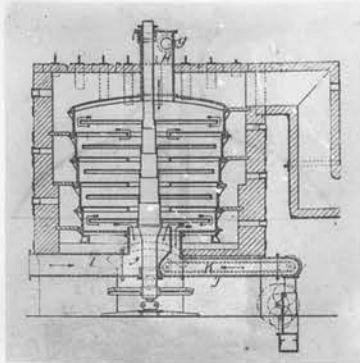


51. Imray's annular lead bath retort. (Pat. No. 325 of 1872).

52. Paterson's inclined screw operated iron retort. (Pat. No. 569 of 1873).

53. Fife & Bowers chain operated horizontal iron retort. (Pat. No. 101 of 1875).

54. Brewer's vertical iron retort with rotating core. (Pat. No. 3379 of 1881).

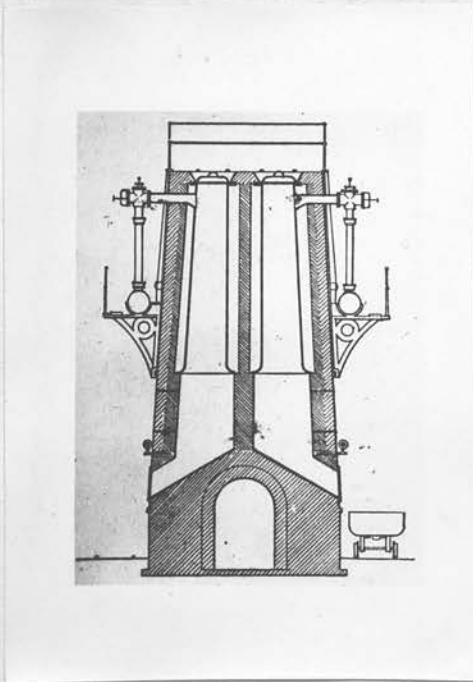
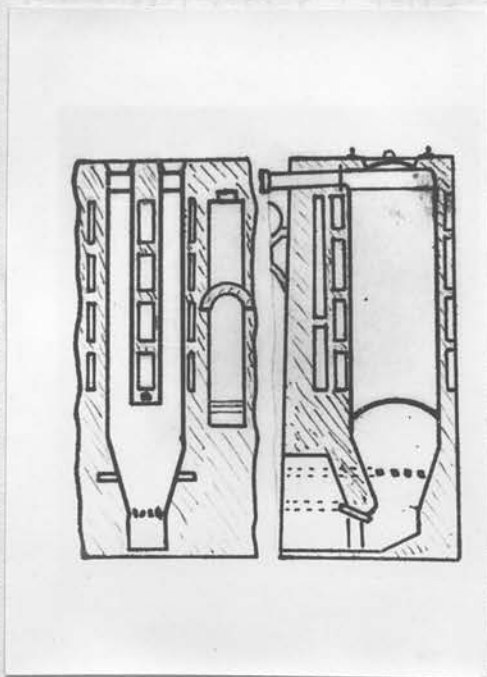
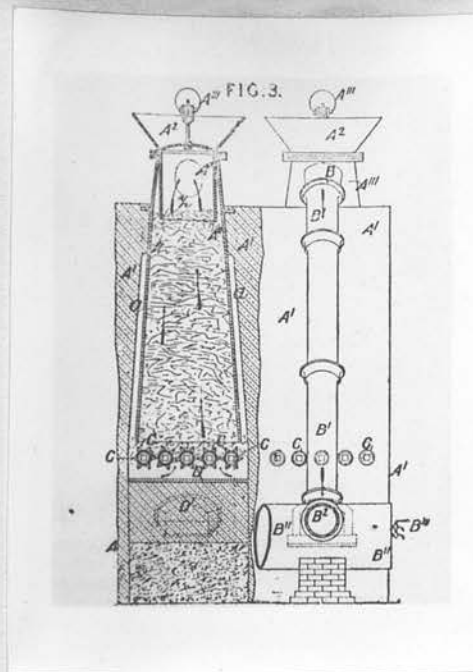
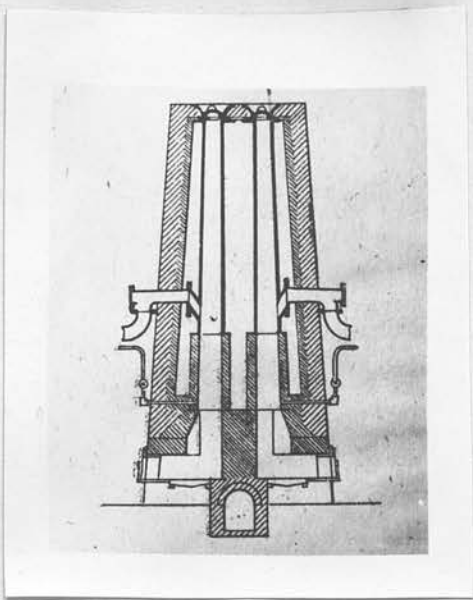


55. Haig's vertical iron retort with internal trays and scrapers. (Pat. No. 6242 of 1889).

56. McEwan's chain operated lead bath retort. (Pat. No. 14617 of 1895).

57. Jas. Young's internal combustion retort, condenser and scrubber. (Pat. No. 618 of 1872.)

58. Kennelly's internal combustion retort. (Pat. No. 2813 of 1873).



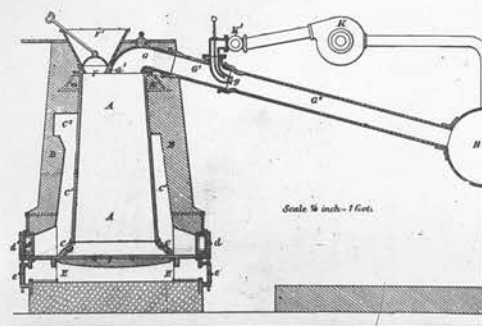
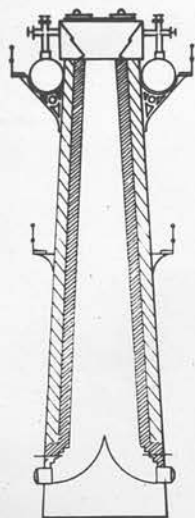
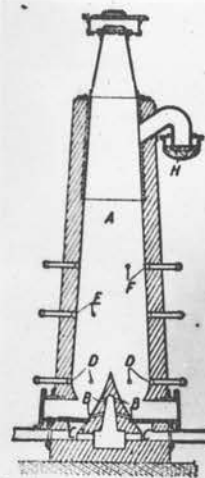
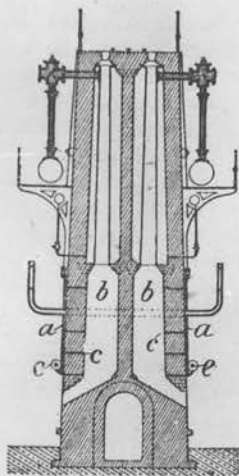
59. Young, Scott & Stephen's  
"Gas Lute" retort. (Pat. No.  
2587 of 1872).

60. McBeath's internal combustion  
retort with mechanically  
operated firebars.  
(Pat. No. 601 of 1874).

61. Thomson & Neilson's internal  
combustion retort. (Pat. No.  
4769 of 1882).

62. Cooper & Rae's internal  
combustion retort.  
(Pat. No. 5724 of 1883).



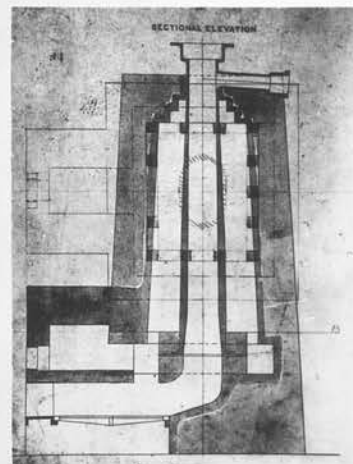
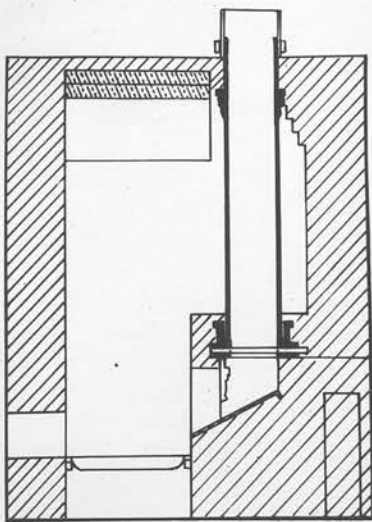
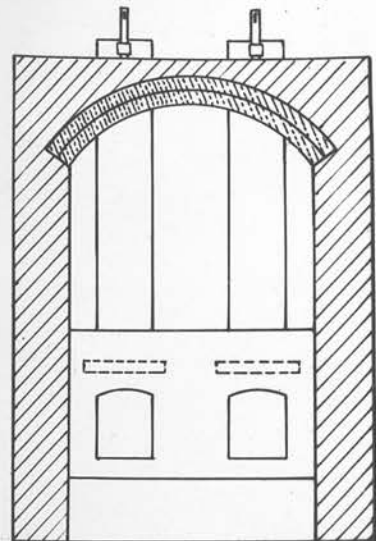
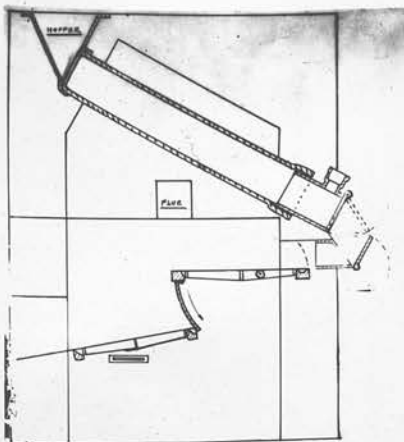


63. Dow's internal combustion retort. (Pat. No. 12286 of 1884).

65. Neilson & Black's "Stanrigg" internal combustion retort. (Pat. No. 9783 of 1889).

64. Aitken's internal combustion retort with provision for recirculation of incondensable gas. (Pat. No. 6048 of 1885).

66. McBeath's vertical iron retort designed to use spent shale as fuel. (Pat. No. 2788 of 1866).

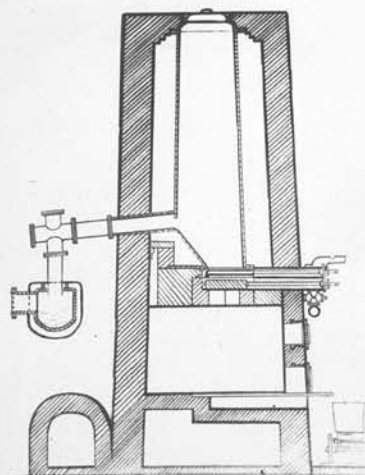
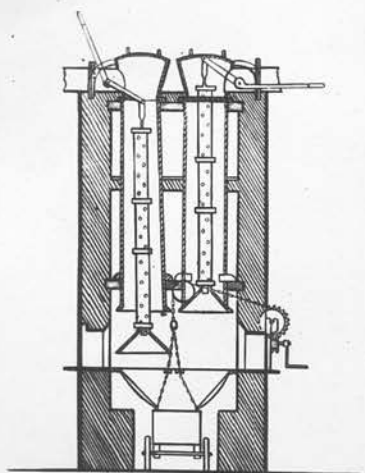
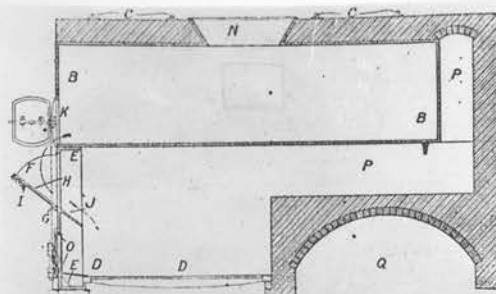
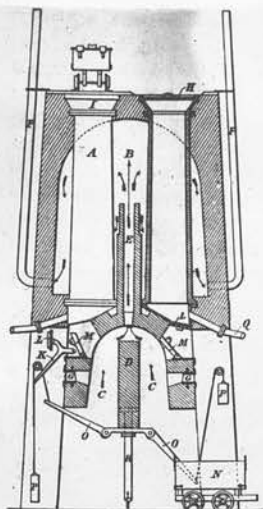


67. Drawing from Bathgate Works showing an inclined retort designed to use spent shale as fuel. (Undated but probably 1865/70).

69. Cross section of "Wedge" discharge retorts showing "Wedge".

68. Vertical iron retorts mounted in pairs and fitted with "Wedge" discharge. (Bathgate 1872).

70. Vertical iron retort adapted for using spent shale as fuel and provision for burning refinery tar also. (Addiewell 1873.).

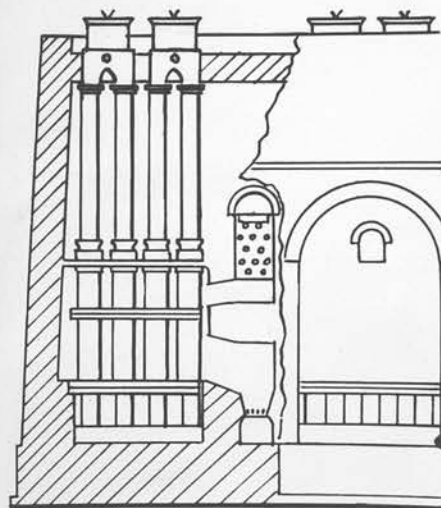
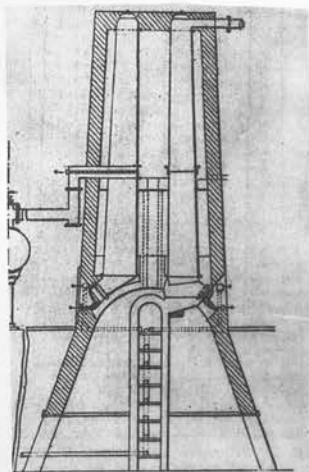
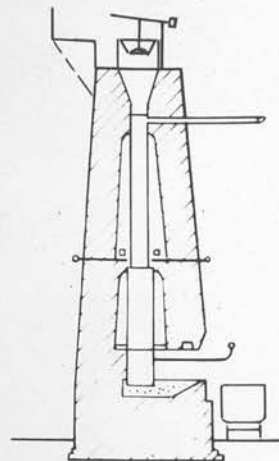
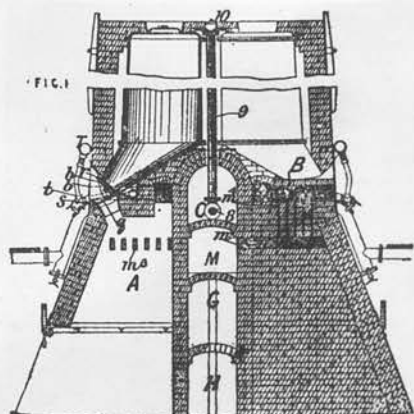


71. N.M. Henderson's retort designed for downward distillation and the use of spent shale and (incondensable) gas as fuel. (Pat. No. 1327 of 1873).

73. Bennie's vertical retort using spent shale as fuel. (Pat. No. 3934 of 1875).

72. Bell's adaption of the "Edge" retort to utilise spent shale as fuel. (Pat. No. 3910 of 1873).

74. W. Young, Neilson & A. Young's thin section vertical iron retort with provision for burning spent shale as fuel. (Pat. No. 3894 of 1876).



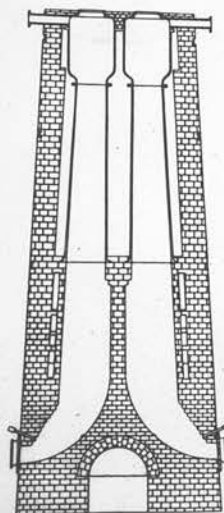
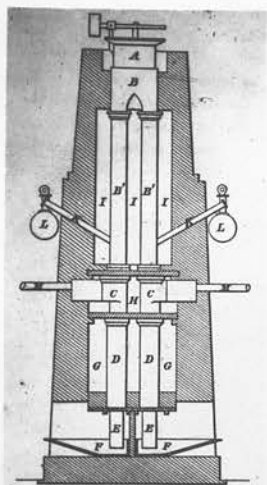
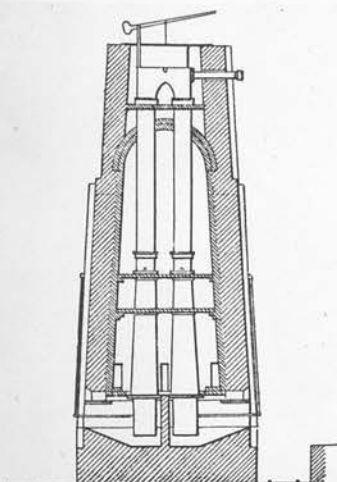
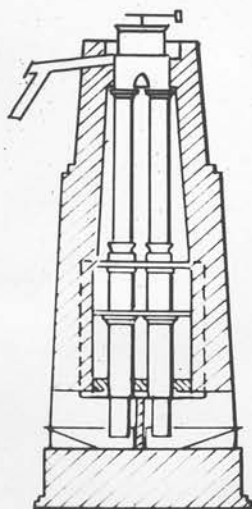
75. W. Young's thin section vertical iron retort (10'x 5' x 1') with spent shale and coal furnaces.  
(Pat. No. 1578 of 1880).

77. W. Young's two stage, all iron vertical retort for oil and ammonia recovery.  
(Pat. No. 2169 of 1881).

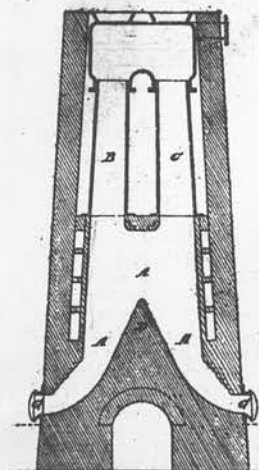
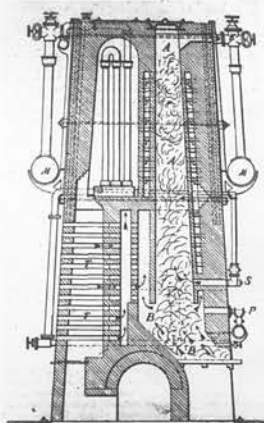
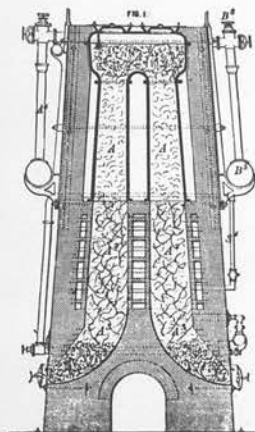
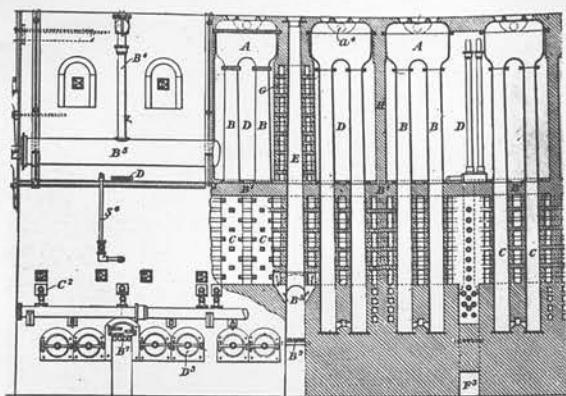
76. G.T. Beilby's experimental iron and fireclay tube retort built at Oakbank Works in 1880.

78. Part section of bench of 16 iron and fireclay tube retorts built at Oakbank Works by G.T. Beilby in 1881).





79. Transverse section of bench of Beilby's 1881 retorts.
80. An improved form of Beilby retorts with 6 retorts to each setting. 1882.
81. A modified Beilby retort with downward distillation in the metal section.
82. An early form of Pentland composite retort with separate raw shale hopper to each retort.

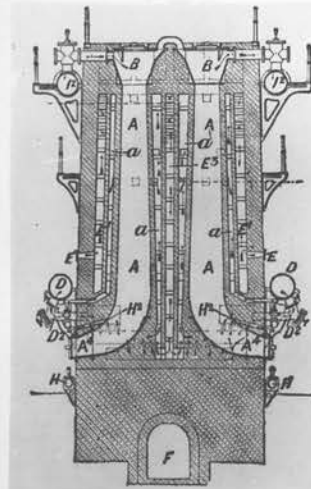
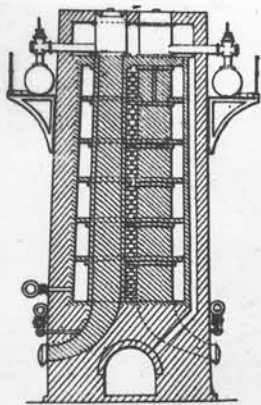
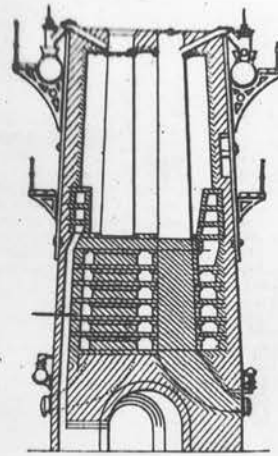
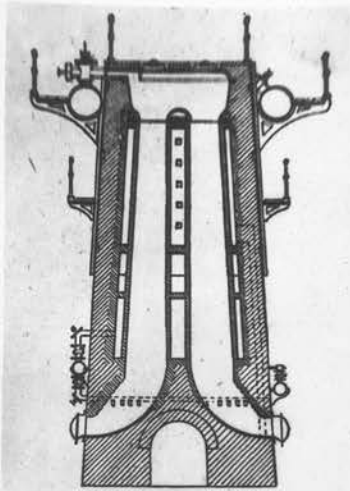


83. Elevation and part section of Pentland retort bench (1883).

84. Section through Pentland shale retorts (1883).

85. Section through Gas Producer Retort of Pentland bench (1883).

86. Jones' modification of the Pentland retort. (Pat. No. 11134 of 1886).

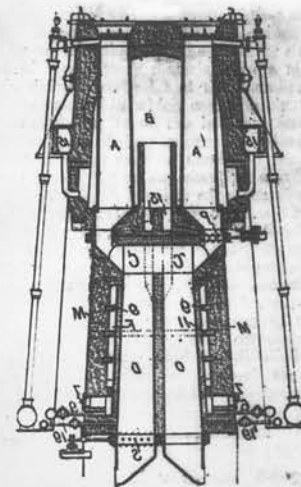
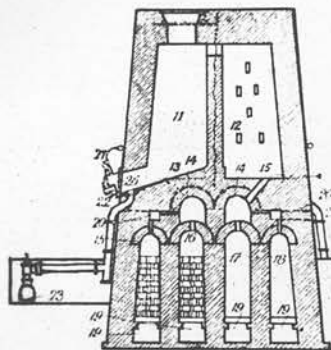
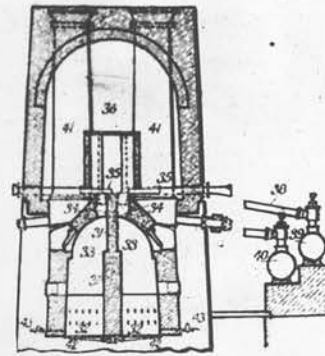
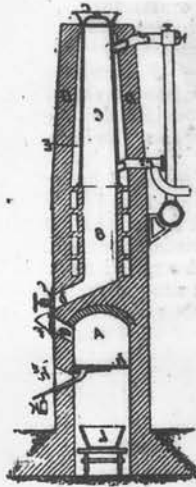


87. Section through a bench of all-brick Pentland Retorts. (1884).

88. Armour's "Breich" retort (section) 1885.

89. Armour's Hermand retort (section) 1889.

90. The "Tennant" all brick retort (Pumpherson 1886/7). (Pat. No. 15772 of 1886).



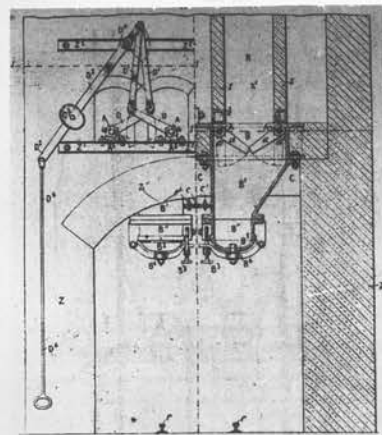
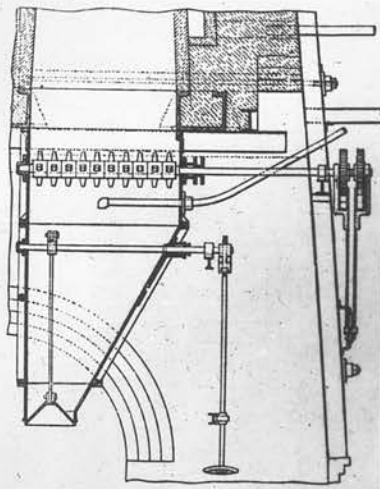
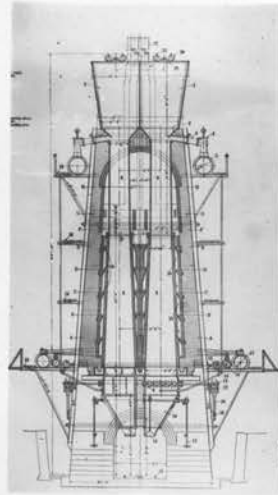
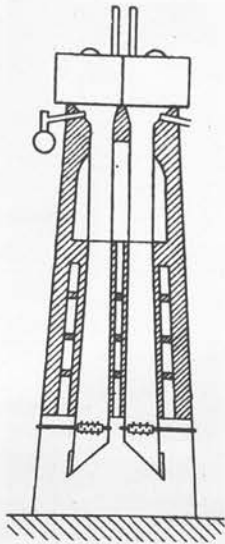
91. R. Bell's composite retort with furnace for spent shale. (Pat. No. 9285 of 1884).

92. N.M. Henderson's modification of his 1873 retort to give maximum ammonia recovery. (Pat. No. 5873 of 1883).

93. N.M. Henderson's all brick two stage retort for maximum ammonia recovery. (Pat. No. 5873 of 1883).

94. N.M. Henderson's first mechanically operated two stage composite retort. (Pat. No. 6726 of 1889). The "Maybrick" retort.



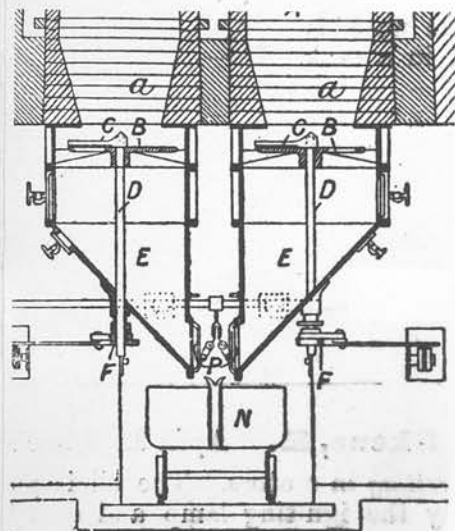
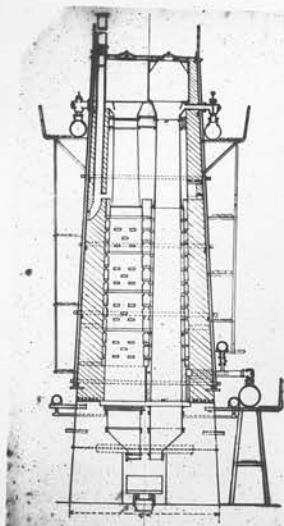
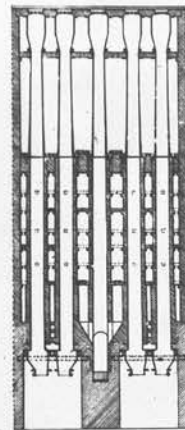
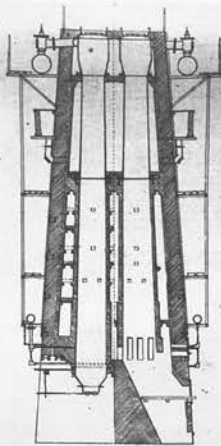


95. N.M. Henderson's improved two stage mechanical retort (1890).

97. Details of the spent shale hopper and extraction gear of "Broxburn" retort.

96. N.M. Henderson's "Broxburn" retort of 1901.  
(Pat. No. 2664 of 1901).

98. Spent shale extraction gear - Orr & Sutherland.  
(Pat. No. 15552 of 1891).

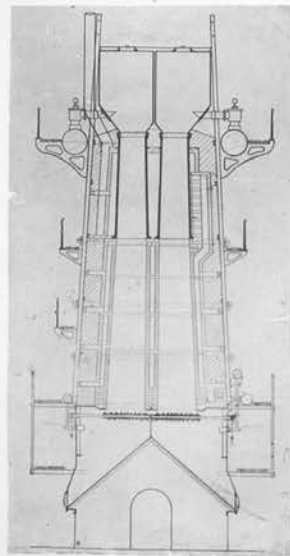
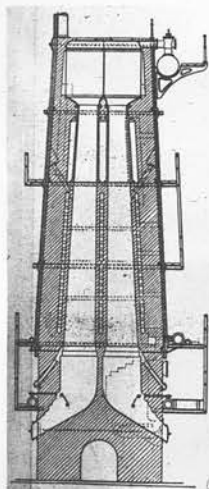
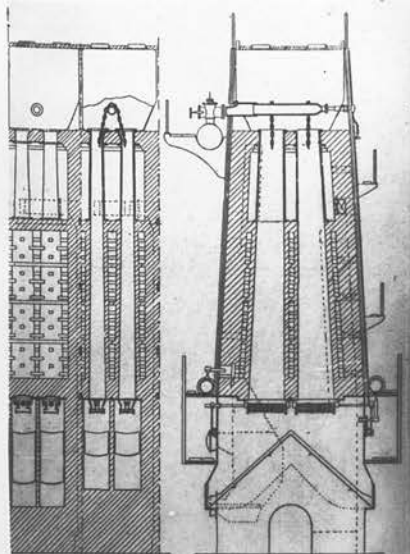
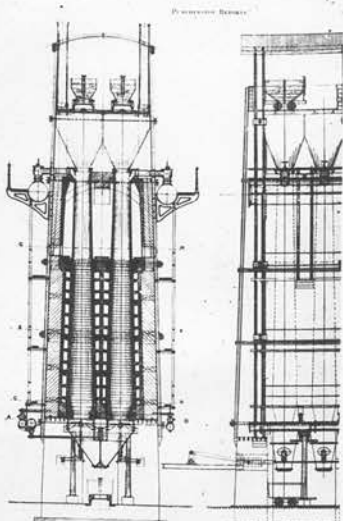


99. Transverse section of the  
"Philpstoun" retort 1893.

100. Longitudinal section of the  
"Philpstoun" retort of  
1893.

101. An improved form of the  
"Philpstoun" retort.

102. Spent shale hoppers and  
discharge mechanism of  
the earliest "Pumpherston"  
retorts.

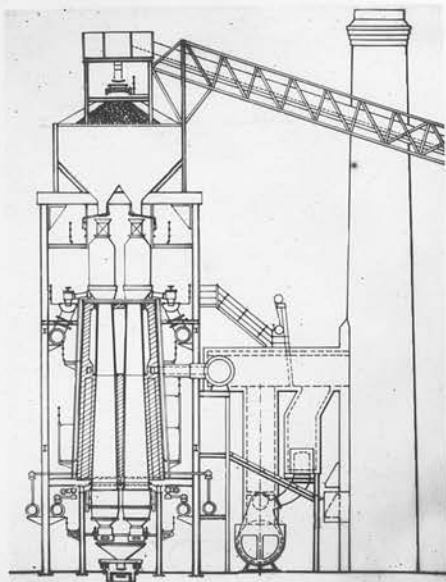
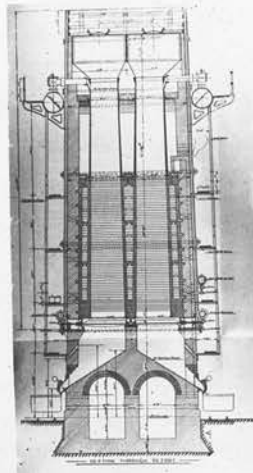
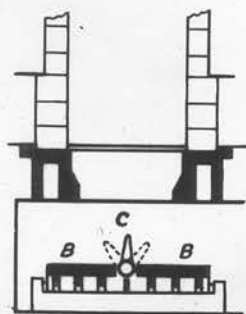


103. Cross section and elevation of the "Pumpherson" retort (Pats. Nos. 8371 of 1894, 7113 of 1895 and 4249 of 1897).

104. W. Young's first mechanical two stage composite retort. (Pat. No. 13665 of 1897).

105. W. Young's manually operated composite retort designed for air injection at the base. (Pat. No. 15238 of 1899).

106. The "Young & Fyfe" retort of 1904.



107. A.C. Thomson's spent shale extraction gear for rectangular sectioned retorts. (Pat. No. 9944 of 1896).

108. The "Oakbank" retort incorporating the above gear. (Pat. No. 6784 of 1915).

109. Cross section of a bench of "Westwood" Retorts showing overhead shale hoppers, belt conveyors, waste heat boilers etc. (1940).



## 9. SOURCE OF ILLUSTRATIONS.

9. SOURCE OF ILLUSTRATIONS

- No. 1. From specification of Patent No. 10726 of 1845.
- No. 2. " " " " No. 516 of 1856.
- Nos. 3, 4 & 5 From Bathgate Works drawing dated 1865.
- " 6, 7 & 8 From "Mineral Oils and Their Bye-Products". I.J. Redwood 1897. p. 60.
- No. 9. From J.S.C.I. 1897 - No. II Vol. XVI. - p. 876.
- No. 10 From Drawing by Bell dated "Wishaw" 1863".
- No. 11 From Bathgate Works drawing dated 1865.
- No. 12 From "Mineral Oils and Their Bye-Products" I.J. Redwood 1897. p. 61.
- No. 13 From Bathgate Works drawing dated 1867.
- Nos. 14 & 15 From "A Treatise on Petroleum" B. Redwood. 1926 Vol. 2. p. 612.
- Nos. 16, 17 and 18 From a Works drawing dated 1877, Addiewell.
- Nos. 19, 20 and 21 From a Bathgate Works drawing 1862.
- Nos. 22, 23 and 24 From a tracing of a Bathgate or Addiewell Works drawing not dated but probably about 1865/1870 (Marked "first bench of 12 retorts").
- Nos. 25, 26 and 27 From an Addiewell Works drawing dated 1877.
- No. 28 From J.S.C.I. 1897, No. II. Vol. XVI - p. 878.
- No. 29 From specification of Patent No. 3224 of 1869.
- No. 30 From J.S.C.I. 1897, No. II. Vol. XVI - p. 878.
- No. 31 From sketch and notes loaned by J.H. Hope Esq.
- No. 32 From drawing marked Midlothian Oil Co. 1872.
- No. 33 From specification of Patent No. 930 of 1875.
- No. 34 " " " " No. 1481 of 1868.
- No. 35 " " " " No. 1361 of 1865.
- No. 36 /

9. SOURCE OF ILLUSTRATIONS Continued

No. 36	From specification of Patent No. 2080 of 1863.			
No. 37	"	"	"	No. 1553 of 1865.
Nos. 38 & 39	"	"	"	No. 486 of 1861.
No. 40	"	"	"	No. 69995 of 1884.
Nos. 41 & 42	"	"	"	No. 1349 of 1864.
No. 43	"	"	"	No. 650 of 1867.
No. 44	"	"	"	No. 992 of 1866,
No. 45	"	"	"	No. 1698 of 1859.
No. 46	"	"	"	No. 1940 of 1862.
No. 47	"	"	"	No. 1076 of 1865.
No. 48	"	"	"	No. 478 of 1866.
No. 49	"	"	"	No. 2714 of 1870.
No. 50	"	"	"	No. 1494 of 1872.
No. 51	"	"	"	No. 325 of 1872.
No. 52	"	"	"	No. 569 of 1873.
No. 53	"	"	"	No. 101 of 1875.
No. 54	"	"	"	No. 3379 of 1881.
No. 55	"	"	"	No. 6242 of 1889.
No. 56	"	"	"	No. 14617 of 1895.
No. 57	"	"	"	No. 618 of 1872.
No. 58	"	"	"	No. 2813 of 1873.
No. 59	From J.S.C.I. 1897, No. II. Vol. XVI - p. 877.			
No. 60	From specification of Patent No. 601 of 1874.			
No. 61	"	"	"	No. 4769 of 1882.
No. 62	"	"	"	No. 5724 of 1883.
No. 63 /	"	"	"	

9. SOURCE OF ILLUSTRATIONS Continued

- No. 63 From specification of Patent No. 12286 of 1884.
- No. 64 " " " " No. 6048 of 1885.
- No. 65 " " " " No. 9783 of 1889.
- No. 66 " " " " No. 2788 of 1866.
- No. 67. From Bathgate Works pencil drawing. Undated but probably 1865/70.
- Nos. 68 & 69 From Bathgate Works drawing of 1872.
- No. 70 From photograph of an Addiewell Works drawing dated 1873.
- No. 71 From "Mineral Oils & Their Bye-Products" I.J. Redwood 1897 p. 72.
- No. 72 From specification of Patent No. 3910 of 1873.
- No. 73 " " " " No. 3934 of 1875.
- No. 74 " " " " No. 3894 of 1876.
- No. 75 " " " " No. 1578 of 1880.
- No. 76 From The Journal of the Society of Arts Vol. 33, 1885, Feb. 20th.
- No. 77 From specification of Patent No. 2169 of 1881.
- No. 78 From The Journal of the Society of Arts Vol. 33, 1885, Feb. 20th.
- No. 79. Ditto.
- No. 80 From J.S.C.I., 1897, No. II, Vol. XVI.
- No. 81 From "Mineral Oils & Their Bye-Products" I.J. Redwood 1897.
- No. 82 From "The Oil Shales of the Lothians" H.M.S.O., 1927, p. 254.
- No. 83 From "Mineral Oils & Their Bye-Products" I.J. Redwood 1897, p. 85.
- Nos. 84 & 85 From "Mineral Oils & Their Bye-Products" I.J. Redwood 1897, p. 85.
- No. 86 /



9. SOURCE OF ILLUSTRATIONS Continued

- No. 86 From specification of Patent No. 11134 of 1886.
- No. 87 From J.S.C.I. 1897, No. II, Vol. XVI. p. 880.
- Nos. 88 & 89 From J.S.C.I. 1891, No. 5, Vol. X. p. 440.
- No. 90. From specification of Patent No. 15772 of 1886.
- No. 91 " " " " No. 9285 of 1884.
- Nos. 92 & 93 " " " " No. 5873 of 1883.
- No. 94 " " " " No. 6726 of 1889.
- No. 95 From Broxburn Works drawing dated 1890.
- No. 96 From U.S.B.M. Bulletin 1924 - "Oil Shale" - J. Gavin.
- No. 97 From "A Treatise on Petroleum" - Sir B. Redwood. 1926  
Vol. 2 p. 622.
- Nos. 98, 99  
and 100 From J.S.C.I., 1897, No. 12, Vol. XVI.
- No. 101 From Philpstoun Works drawing dated 1913.
- No. 102 From specification of Patent No. 8371 of 1894.
- No. 103 From J.S.C.I., 1897, No. 12, Vol. XVI.
- No. 104 From "A Treatise on Petroleum" - Sir B. Redwood. 1926  
Vol. 2. p. 620.
- No. 105 From "A Treatise on Petroleum" - Sir B. Redwood. 1926  
Vol. 2. p. 621.
- No. 106 From a working drawing of the Young & Fyfe retort.
- No. 107 From specification of Patent No. 9944 of 1896.
- No. 108 From "A Treatise on Petroleum" - Sir B. Redwood. 1926  
Vol. 2. p. 621.
- No. 109 From a Westwood Works drawing dated 1940.